1916.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 68.

THE GEOLOGY AND ORE-DEPOSITS

OF

MEEKATHARRA, MURCHISON GOLDFIELD,

BY

E. deC. CLARKE.

Petrology by R. A. FARQUHARSON.

Mineralogy and Underground Waters by
E. S. SIMPSON.

Issued under the Authority of
The Hon. P. Collier, M.L.A., Minister for Mines.

WITH TWENTY-FIVE PLATES AND EIGHTY-EIGHT FIGURES

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

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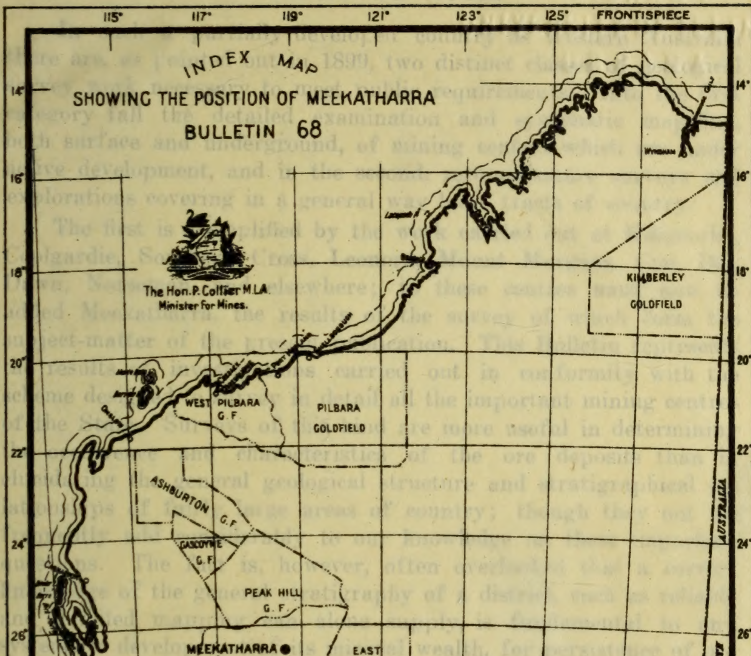


H. J. Pether, Government Lithographer, Perth, W.A.

PREFATORY NOTE.

In such a partially developed country as Western Australia there are, as pointed out in 1899, two distinct classes of geological survey work necessary to meet public requirements. Into the first category fall the detailed examination and systematic mapping, both surface and underground, of mining centres which are under active development, and in the second, reconnaissance surveys and explorations covering in a general way large tracts of country.

The first is exemplified by the work carried out at Kalgoorlie, Coolgardie, Southern Cross, Leonora, Mount Morgans, Cue, Day Dawn, Norseman, and elsewhere; to these centres must now be added Meekatharra, the results of the survey of which form the subject-matter of the present publication. This Bulletin represents the results of investigations carried out in conformity with the scheme designed to survey in detail all the important mining centres of the State. Surveys of this kind are more useful in determining the occurrence and characteristics of the ore deposits than in elucidating the general geological structure and stratigraphical relationships of fairly large areas of country; though they not infrequently add considerably to our knowledge on these important questions. The fact is, however, often overlooked that a correct knowledge of the general stratigraphy of a district, such as reliable and detailed mapping can alone supply, is fundamental to any systematic development of its mineral wealth, for persistence of ore deposits is rather a function of geological structure than depth.

No detailed and systematic work dealing with the geology and ore deposits of Meekatharra has been officially undertaken prior to this report.

The field work at Meekatharra was carried out, with some unavoidable interruptions, by Mr. E. de C. Clarke, Field Geologist, between the months of July, 1913, and January, 1915. The initial work, however, was commenced in 1910 by Mr. H. W. B. Talbot, who devoted about seven months to the preparation of a topographical map, to be used as a basis for the geological work. The results of Mr. Talbot's survey were plotted on the scale of 10 chains per inch, and included an area of about 200 square miles.

The country embraced by the survey falls within the 20-chain lithograph $L\frac{66^{3}}{66}$ and the 40-chain lithographs L66 and L66A issued by the Department of Mines, as well as a portion of sheet 59 of the 300-chain series of maps of the Department of Lands and Surveys.

The mining centre of Meekatharra is situated in South Latitude 26deg. 30min., on the great central plateau of Western Australia,

at an altitude of about 1,700 feet above sea-level, and on the divide separating the areas of exterior and interior drainage. The principal streams belonging to the system of exterior drainage all discharge into the Murchison River, which flows westward into the Indian Ocean, whilst those of the interior drainage system flow southwards into the inland basin of Lake Annean. There are sound scientific reasons for believing that the exterior system of drainage is gradually encroaching on the interior.

The average rainfall of the district is low, viz., about 10 inches, and being very irregular there is no surface water except at very rare intervals.

The geological constitution of Meekatharra consists in the main of a complex of crystalline rocks comprising granitic, doleritic, and peridotitic types.

Upon this ancient complex of crystalline rocks, a series of bedded deposits, chiefly arkose, conglomerate and indurated black slate, was laid down; to this succeeded the great outburst of granite, and allied acid igneous rocks which, just to the north of Meekatharra, enclosed, compressed and otherwise altered the sediments to such an extent that it is not now readily possible to differentiate them from the rocks upon which they were originally deposited.

The granitic rocks occupy the western portion of Meekatharra area, and form a band of about two or three miles in width with a general north-easterly strike. The granite is intrusive into the older crystalline complex and sends out veins into the basic rocks, in addition to containing masses of the latter along its eastern margin. Of the granite two lithological types have been recognised, viz., (a) a hornblende granite (or quartz-diorite) in which the felspars are often represented by epidote, and (b) a biotite-microcline granite. There are also gradational types which point to an intimate relationship between the two varieties; the field-work, however, shows that the two granites form part of one and the same mass.

An important feature in the area is the number of acidic dykes which intersect the older rocks of Meekatharra; these, in all probability, form the apophyses of the large granite mass to the west of the ore-bearing belt, and there is a close geological kinship between many of the auriferous deposits and the acid dykes.

By far the largest and most important part of the field is made up of a congeries of basic rocks, having a considerable petrological range, though linked together by ties of affinity, and comprise two main groups, viz.:—

(a) The comparatively fresh greenstones which include dolerite, norite, amphibolite, epidiorite, and serpentine; and

(b) much altered chloritic, carbonated and talcose rocks, in which the individuality and geological identity appear to have been almost entirely lost, due perhaps in part to the thermal metamorphism of the granite.

The relation of the various rock types to one another is not in all cases quite clear, hence the geological age of these cannot be said to have, as yet, been definitely established.

The serpentines have a general parallelism to the prevailing strike of the schists, and from the mode of occurrence of that associated with the ore-bearing belt, it may, perhaps, represent an intrusion sill-like in character.

Unaltered dolerite dykes occur in several localities within the area mapped; they probably represent one of the latest, if not the last, phase of eruptive activity in this portion of the Murchison field, and may be connected with that huge reservoir of molten matter which lay beneath the surface to the north of latitude 26 deg., awaiting a suitable opportunity of rising to the surface. These dolerite dykes are found in some of the mine workings of the main auriferous belt; they are younger than the ore and are in no way genetically connected therewith.

Associated with these basic rocks is a series of volcanic beds in the form of flows of basalt and andesite, together with breccias and tuffs in a fresh state of preservation. They occur just to the east of the Meekatharra gold-bearing belt of Paddy's Flat, and are believed to be of Devonian Age.

A series of highly inclined sedimentary rocks, in the form of arkoses, grits and conglomerates, occur a short distance to the north-east of Meekatharra adjoining the south-eastern edge of the granite; these occasionally contain small quartz veins, indicating that they were formed prior to the mineralisation of the district; they owe their present position to tectonic disturbances.

A very conspicuous feature in the field is that complex set of structures, now represented by bands of jaspilite often having a ribbon-like structure. These bands, which have a general strike of north-north-east, owe their origin to compression and intense shearing and a subsequent metasomatic replacement of the fine-grained chloritic schists through the action of carbonated waters.

The underground water-level in the district is usually below 100 feet in depth, and it is only very rarely that any large quantity of meteoric water reaches the supply already stored in the rocks. The underground waters, of which several samples have been analysed, prove to be of one general type, and in all probability owe the concentration of the contained salts, in part to residual oceanic waters, to rain, and to local weathering of rocks and lodes. The waters would not, however, appear to have played any part in

ore deposition. To what extent the composition of the underground waters has been influenced by residual magmatic water there is no evidence at present available.

The ore deposits of Meekatharra are almost entirely restricted to the eastern portion of the field and are mainly confined to the neighbourhood of the granite. They have a more or less definite strike, which is north-north-east, being that of the main tectonic lines of the field. When viewed broadly the ore deposits consist of veins and lodes. The veins are principally quartz, some of which are probably but an ultra-acid phase of the porphyry dykes, whilst the lodes consist of (a) deposits which owe their origin to metalliferous solutions emanating from the acid magma which constituted the primary source of the granite, and (b) siliceous impregnations of zones of sheared country rock. The ore deposits contain but a small number of minerals other than the gold contents; the quartz and allied veins are usually destitute of minerals, whilst the metasomatic auriferous ore bodies contain arsenopyrite, as the most important metallic mineral, though pyrites occurs in smaller proportions.

Of the geological age of the auriferous deposits there is, at the present time, no direct evidence, although everything points to the Pre-Cambrian as being the most probable; but while this may be the case it does not follow that the fissuring and mineralisation were necessarily contemporaneous. The deposits would appear to have closely followed the intrusion of the Meekatharra granite, which is, perhaps, from the economic point of view, the most important geological event at this period.

The graph and figures relating to gold production have been compiled from data furnished by the statistical branch of the Mines Department; and in the form in which they are presented, the data furnish as complete a record of the yield of the various deposits of Meekatharra as possible. The returns show that, up to the end of 1914, the total output from the area embraced by the survey amounted to 404,814 ounces of fine gold, together with 2,159.52 ounces of fine silver, derived from the milling of 572,670 tons of ore, or an average of .7 ounces of fine gold per ton.

Full and detailed descriptions, illustrated wherever possible by geological plans and sections, are given of those mines in active operation or otherwise accessible, as occurred in the district embraced by the survey. The geological maps and sections of the underground workings of the principal mines, without which the text would be well-nigh unintelligible, have been based on the plans which the owners lodge with the Department of Mines in compliance with the Mines Regulation Act, and in those cases where no plans are available, tape and compass surveys have been made by Mr. Clarke. The underground mapping of the lodes and fissures

and their presentation on a uniform scale both in plan and section, should tend to materially facilitate future exploration work.

The abandoned workings on the field, however, do not of necessity imply that the deposits have been exhausted, for it is possible that many may be reopened and possibly worked under more favourable economic conditions than at present prevail, though if the gold production of Meekatharra is to be maintained or increased it will be largely, if not entirely, due to the few larger mines at present existing.

The chemical and mineralogical work arising out of the field work has been carried out in the Survey laboratory under the general direction of Mr. Simpson.

The petrological work is the result of the labours of Mr. Farquharson.

A representative collection of minerals, ores, and rocks has been made during the course of the survey and deposited for reference in the Departmental Collection.

A. Gibb Maitland,

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 1st June, 1916.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

LIST OF OFFICERS.

Government Geologist .. .. A. Gibb Maitland

(Director of the Survey.)

Field Staff.

Assistant Government Geologist	*Vacant.*
Assistant Geologist	T. Blatchford
Field Geologist	J. T. Jutson
Do.	H. W. B. Talbot
Do.	E. de C. Clarke
Do.	F. R. Feldtmann
Do.	*C. S. Honman

Laboratory Staff:

Mineralogist and Chemist—E. S. Simpson.

Assistant Mineralogist and Chemist—H. Bowley.

Assistant Mineralogist and Chemist—D. G. Murray.

Petrological Staff:

Petrologist—R. A. Farquharson.

Drafting Room.

Draftsmen .. .. R. H. Irwin and C. B. Kidson.

Office Staff.

Clerk-in-Charge and Librarian	P. J. Atkins.
Clerk and Typist	*J. D. Glover.
	L. A. Taylor (*acting*).
Messenger	R. Connolly.
General Assistant	B. S. Welsh.

*Absent with Expeditionary Forces.

TABLE OF CONTENTS.

TABLE OF CONTENTS—*continued.*

TABLE OF CONTENTS—*continued.*

CHAPTER V.—LODES AND VEINS.

CHAPTER VI.—MINES.

TABLE OF CONTENTS—*continued.*

TABLE OF CONTENTS—*continued.*

TABLE OF CONTENTS—*continued.*

Chapter VII.—Petrology

Chapter VIII.—The Minerals of the Meekatharra District.

TABLE OF CONTENTS—*continued.*

CHAPTER IX.—THE UNDERGROUND WATERS OF MEEKATHARRA.

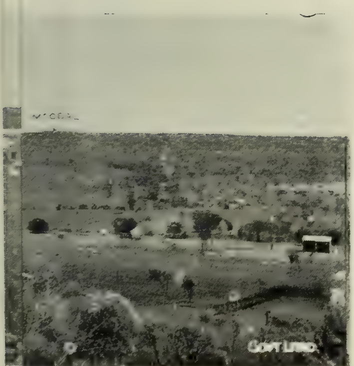
LIST OF PLATES.

(In separate atlas.)

LIST OF FIGURES.

LIST OF FIGURES—*continued.*

LIST OF FIGURES—*continued.*



Negs. 1402-3-4-5.

Negs. 1407-8-9-10.

Fig. 1. Mt. Yagahong—from the South-West. Negs. 1218-19.

Fig. 2. Panorama of Meekatharra Township from Luke's Trig. Negs. 1102 3 4 5.

Fig. 3. Photos. by E. de C. Clarke. Panorama of the Paddy's Flat Belt. Negs. 1107 8 9 10.

CHAPTER I.

GENERAL INFORMATION.

I.—INTRODUCTORY.

The town of Meekatharra (fig. 2), which, geographically and economically, is the centre of the District*, has a population of about 1,500, is situated in the Murchison Goldfield at the terminus of the Northern Railway, and is, by rail, 334 miles from Geraldton and 600 miles from Perth (*see* Frontispiece).

The Area*, which includes one of the youngest of the well-established gold-mining centres of the State, has shown an almost continuous advance in gold production since the beginning of its mining activity. During 1914 it possessed eight mines fully, and five partially, equipped with steam- and gas-driven plants, in addition to which about fifteen leases with more primitive appliances were raising ore to be crushed at the State Battery. In 1914, 133,965.3 tons of ore were treated, giving a return of 76,025.92 fine ounces of gold†, and 1,341.85 fine ounces of silver. The total output of the Area to the end of 1914 was 404,814.11 fine ounces of gold and 2,159.52 fine ounces of silver from 572,670.63 tons of ore—an average of about .7 ounces of gold per ton. The annual gold-output and ore-tonnage are graphically shown in Plate I.

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* For explanations of the terms District, Area, etc., as used in this Bulletin, *see* pp. 23, 24.

† Including dollied and specimen gold.

For many years before its mineral wealth was suspected much of the Murchison Goldfield had been held in large blocks by pastoralists. The District is now fenced into great paddocks. Stock is usually watered from wells fitted with automatically regulated windmills. The almost universal presence of stock-water at depths seldom exceeding 50 feet greatly lessens the expenses and

Fig. 4.

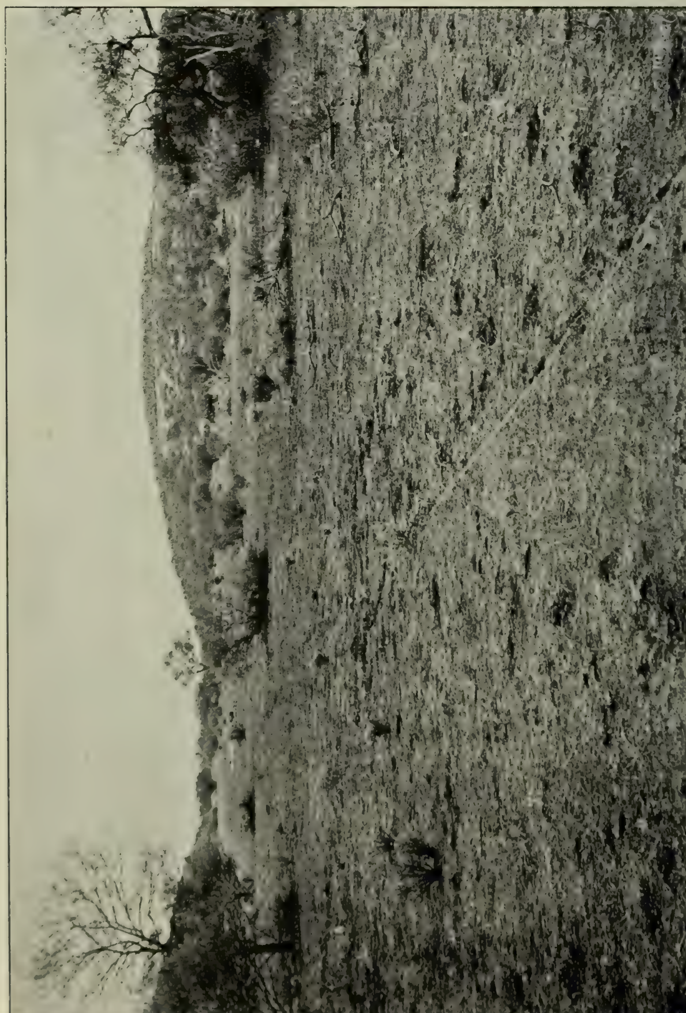

Photo.: E. de C. Clarke. Neg. 1398.

Hill of "Southern Cross" Granite, Three miles S.W. of Yaloginda.

Note.—Hill-top is covered with large boulders of weathered granite, which, slipping away from hillside, leave a curved surface of harder granite.

losses of run-holders in exceptionally dry seasons when feed is reduced to a minimum.

The town and the chief mining belt (*see* fig. 3), which lies about one mile east of the town, are supplied with water by the Mines

Fig. 5.

Photo.: H. W. B. Talbot. Neg. 604.
Granite Rocks, $2\frac{1}{4}$ miles N.N.W. of Luke's Trig.

Water Supply Department. The water for domestic use is obtained from wells in decomposed granite, or granite wash, four and a-half miles east of Meekatharra; that for use on the mines is brought from Garden Gully, about 10 miles to the north.

Meekatharra has had direct rail communication with Perth and Geraldton since 1910, the journey to Perth now occupying 34 hours. Telegraphic communication by means of a branch from the main line between Perth and Nullagine is established, and there is a local telephone exchange. Roads, of which the most important have been surveyed, connect the various mines of the Area with Meekatharra. Owing to the level nature of the country and the sparseness of the scrub little is necessary in the way of road-making beyond the removal of a few stumps and boulders.

Fig. 6.

Photo.: E. de C. Clarke. Neg. 1221.

Breakaway in Granite, about 5 miles W. of 50-M.P., Peak Hill Road

The scenery of the District is of the monotonous type characteristic of the interior parts of Western Australia. One-third of it consists of plain-country. The more broken parts are generally made up of granite hills and breakaways (figs. 4, 5, and 6) or of

greenstone hills and ridges (figs. 7 and 8) seldom rising more than 100 feet above the plain-country. In addition may be noted the

Fig. 7.

Photo.: H. W. B. Talbot. Neg. 609.

Bluff on Jasper Ridge, about one mile south of Fenian G.M.

two mesas—Yagahong and Table Top Hill (figs. 1 and 15). Hills and plains are alike covered with a sparse growth of "mulga," and the reddish soil—generally strewn with boulders and pebbles of quartz, impure ironstone and ironstained rock—is devoid of other

vegetation except after heavy rain, when a luxuriant growth of herbs and grasses quickly appears, followed by an amazing variety of flowers.

As is generally the case in the goldfields of Western Australia, "The heat (in summer) is very disagreeable indeed, whilst the inhabitants as a rule find all the recognised languages quite inadequate for a description of the flies and dust. As a kind of compensation, the winter season is delightful. Very little rain falls and the weather is cold, clear, and bracing."*

Fig. 8.

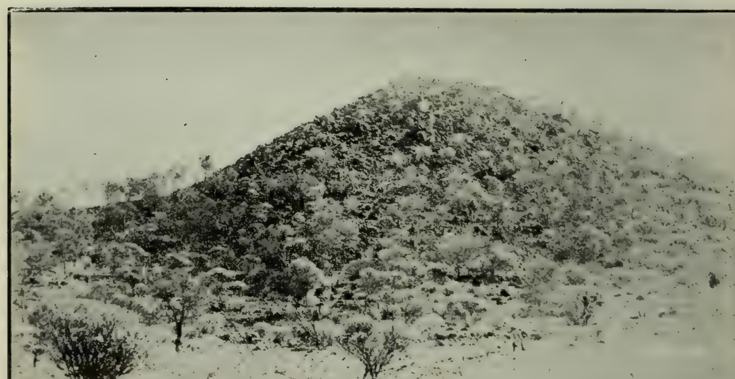

Photo.: E. de C. Clarke. Neg. 1222.

Mt. Obal (Trig. Station K6), west of Meekatharra. A characteristic island hill of quartz dolerite.

II.—PLAN OF CONDUCTING WORK.

The geological survey, the results of which are contained in this Bulletin, was begun in April, 1910, when Mr. H. W. B. Talbot, Field Geologist, spent seven months in making a topographical survey, mapped on a scale of 10 chains to the inch, of about 200 square miles in the Area. This officer, and also Mr. Gibb Maitland, mapped several of the geological features—more particularly the Jasper Bars.

The writer's field-work began in July, 1913, and continued with some interruptions till January, 1915. More than half of the time spent in the district was taken up with examination and (if mine plans were unavailable) survey with tape and prismatic compass, of underground workings. Attention to the surface-geology con-

* Western Australian Year Book, 1902–4, 13th edn., p. 166.

sumed a little less than one-quarter of the period. The rest of the time was devoted to draughting, examination of specimens, and other indoor work necessary during the progress of such a survey.

The methods of field-work and areas over which they were applied may be mentioned so that the value of the facts collected and of the consequent conclusions can be appraised.

A.—Broader Field-Work.

In order that the known geology of this part of the Murchison Goldfield, together with other information useful to prospectors, might become available, the map comprising Plate II. has been compiled from the Lands Department Lithograph 59/300, on which has been placed further information regarding wells, etc., obtained from the Mines Water Supply Department, Mines Department, and other sources, together with geological features noted at various times by Messrs. Maitland, Woodward*, Blatchford, Talbot, C. G. Gibson†, and the writer. The map has been produced on a scale of four miles to one inch and forms one of the new "four-mile series of geological maps."‡

An almost rectangular strip on the eastern side of Plate II. will be referred to as the "Meekatharra District" or "The District." The Meekatharra District has an area of about 2,000 square miles, extending from the latitude of Gabanintha in the south to that of Abbotts, and from the longitude of Belele Station Homestead in the west to that of the 191-mile peg on the No. 2 Rabbit-proof Fence.

Examination of the outlying parts of the District was carried out by driving across them in various directions and fixing the boundaries between the granites, greenstones and sedimentary rocks by reference to road and lease pegs, rough triangulation, etc. No attempt at a more detailed classification than Granites, Greenstones, and Sedimentaries was made in this part of the work.

Superficial deposits—not indicated on Plate II. but covering a large area in the District—very seriously mask the essential geological features so that, on Plate IV. as on the more detailed maps, the geological boundaries are in the main only approximations.

B.—Detailed Field-Work.

That portion of the Meekatharra District examined in more detail (Plate IV.) will, for convenience, be referred to as the "Meekatharra Area" or simply "The Area."

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* Also in G.S.W.A. Bulletin No. 57, Pl. I.

† In G.S.W.A. Bulletin No. 14, pp. 39, 44, etc.

‡ *See* Ann. Prog. Rep. G.S.W.A., 1915, p. 6.

Geological mapping of the Meekatharra Area was greatly facilitated by Mr. Talbot's topographical work, and his geological notes. Mapping of geological boundaries was generally done by the writer with the tacheometer, but in some cases paced compass traverses were found to suffice. This work was plotted on a scale of 10 chains to one inch.

C.—Mining Geology.

In three parts of the Meekatharra Area ore-deposits of a constant type persist for a considerable distance. These deposits and the country bordering on them are described as Paddy's Flat, Yaloginda, and Karangahaki Belts respectively. The smaller deposits and their immediate neighbourhood are generally described as "Groups," which take their names from leases or well-known prospectors associated with them.

In order to investigate the geology of the above, all workings in actual progress, and practically all accessible abandoned workings, were examined and plans (if not already existing) prepared. Nearly all these plans are reproduced in this bulletin—the majority on a scale of 132 feet to one inch on large sheets so that a better idea of the trend of the ores bodies may be given. On these plans superficial deposits are generally ignored (*see* also p. 77) and, wherever possible, geological boundaries, etc., projected to the surface. Apparent discrepancies between the mapped and described positions of geological features relative to workings are thus explained. Plans are also given showing the geology at different levels in the more important mines.

The examination of deserted workings consumed a great deal of time and, though the amount of information obtained was small compared to that received from the miners and others in active "shows," some facts of interest were disclosed, and it is hoped that the plans will be of use to those undertaking fresh ventures in these localities.

Help received from various members of the Geological Survey Staff is acknowledged in the course of this report. The writer also wishes to record, and express his thanks for, the great assistance received during the prosecution of the survey from residents in the District too many to mention by name.

III.—ARRANGEMENT OF THIS BULLETIN.

Those who, though interested in mining in the Area do not wish to follow the detailed geological notes of Chapters IV., V., VII., VIII., and IX., will find at the end of Chapter IV. a summary of the geological structure of the District, and in Chapter VI. a more or

less detailed account of the history, geology, and ore-production of any gold-mining lease about which they desire information. Chapter II., dealing with the history and methods of mining in the Area, and Chapter III. (physiographic), together with this introductory chapter, contain information which may be useful to persons interested in the general features and history of the State. The broad results of the petrological studies have some bearing on the origin of the ore-bodies, and may be found applicable to other regions. These results would lose a great deal of their value and authority if not detailed as they are in Chapter VII. Chapters VIII. and IX. contain accounts of the mineralogy and underground waters.

IV.—PREVIOUS GEOLOGICAL WORK.

In 1894 the earliest geological report on any part of the Meekatharra District was given by Mr. S. Göczel who, in an account of "The Interior Gold Region of Western Australia," has some notes on the "Garden Gully Mine" ("Old Battery Group," *see* p. 99).

Passing reference to the state of mining and very brief accounts of the geology of the District (detailed in the bibliography given below) appeared from time to time until 1904, when were published the results of Mr. C. G. Gibson's investigations into the mining and geology of various centres in the Murchison Goldfield, including parts of the Meekatharra District.

In 1906, 1907, and 1909, Mr. A. Montgomery, the State Mining Engineer, reported in detail on the condition of mining in the District, and his three reports furnish a great deal of informatioin on the character of the ore deposits and the methods by which they have been worked.

In 1910 appeared a short "Preliminary Report on the Ore Bodies of Meekatharra," by Mr. H. P. Woodward.

Reference to the work of Messrs. Maitland and Talbot has already been made.

In 1912 Mr. R. A. Farquharson, in company with Mr. H. P. Woodward, spent a few days in examining the geology of the District. He also investigated and reported on the microscopic structure of several rocks from the Ingliston Extended G.M.

V.—LITERATURE.

The publications mentioned in the preceding section are the most important contributions to our geological knowledge of Meekatharra. The following list contains, it is thought, all articles having any important bearing on the local geology:—

Report on the Murchison Goldfield (Perth: By Authority, 1893), by Harry Page Woodward, F.G.S., F.R.G.S., Government Geologist. Deals with country south of the District.

Report on the Department of Mines for the Year 1894. (Perth: By Authority, 1895, pp. 40 and 41.) A few notes on Garden Gully Mine and a prospecting area, by S. Göczel in his report on "The Interior Gold Region of W.A."

"Murchison Times" (Cue), 1894-1914. Contains occasional references to mining in the Meekatharra Area.

Report of the Department of Mines for the Year 1895, *with supplementary notes on part of* 1896. (Perth: By Authority 1896.) Appendix 10, "Report on Geological Features and State of Development of some Mines in the Nannine District, Murchison G.F., by Frank Reed, Inspector of Mines." p. 47, Notes on "Meekatharra Mine."

"Geological Sketch (Map) of Yalgoo and Murchison to accompany H. P. Woodward's Report"—the report published in 1893.

"Geological Sketch Map Showing the Interior Region of W.A." by S. Göczel. Illustrates his report mentioned above.

Report of the Department of Mines for the Year 1896 *with supplementary Notes on part of* 1897. "Geological Map showing country from Cue to Peak Hill, to accompany Report by Frank Reed."

Annual Progress Report of the Geological Survey for the Year 1898, p. 36. Report of Torrington Blatchford, B.A. Also Plate V. Blatchford traversed part of the country mapped on Plate II. of this Bulletin.

The Geology and Mineral Resources of a part of the Murchison Goldfield, by Chas. G. Gibson, B.E. (G.S.W.A., Bull. No. 14, Perth 1904), pp. 61-74. General geology and account of state of mining.

Annual Progress Report of the Geological Survey for the Year 1903, pp. 125-126. Summary of Gibson's work quoted above.

Reports of the Department of Mines for the Years 1898 *to* 1914. Contain brief references to the state of mining in the Area.

West Australian Mining Industry. Special edition of *Australian Mining Standard,* December 8, 1904, p. 125.

Report of the Department of Mines for the Year 1906, pp. 104 to 108, "Notes on Some of the Mines at Meekatharra," by A. Montgomery, M.A., F.G.S., State Mining Engineer.

Report of the Department of Mines for the Year 1907. Besides brief account of mining progress contains (pp. 107-115) "Report on the Progress of Mining in the Meekatharra District, etc.," by A. Montgomery.

Report of the Department of Mines for the Year 1908, pp. 31-33—account of progress of mining in the Area, by F. J. Lander.

Annual Report of the Geological Survey for the Year 1909, pp. 165-166. "Preliminary Report upon the Ore Bodies of Meekatharra," by H. P. Woodward.

"Meekatharra Miner," 1909-1914. Contains many references to current events in mining. Also some general articles of value.

"Report on the State of Mining Progress in certain Centres in the Murchison and Peak Hill Goldfields," by A. Montgomery, pp. 38-58. (Department of Mines, 1910).

Report of the Department of Mines for the Year 1910. Notes by Inspector Lander.

Report of the Department of Mines for the Year 1911. Notes by Inspector Lander.

Petrological Contributions to the Geology of Western Australia, G.S.W.A., Bulletin No. 43, by R. A. Farquharson, B.A. (Oxon) M.Sc., F.G.S., etc., pp. 69-94. "Observations on some Rocks from the Ingliston Extended Mine, etc."

Annual Report for the Geological Survey for the Year 1913, pp. 25-26. Preliminary account of the Geology of Meekatharra, by E. de C. Clarke.

Journal of Chamber of Mines of W.A., 1915, p. 63. "Notes on the Geology of Meekatharra, Murchison Goldfield, and Surrounding Country," by E. de C Clarke. Reprint of address to prospectors and others at Meekatharra.

Annual Report of the Geological Survey for the Year 1914, pp. 23-25. "Meekatharra and surrounding Country," by E. de C. Clarke.

CHAPTER II.

GENERAL HISTORY, AND PRESENT CONDITION OF MINING IN THE AREA.

I.—GENERAL HISTORY OF MINING.

A.—First Mining Ventures.

Towards the end of 1894, three years after the first discovery of gold in the Murchison (at Nannine), a ten-head battery was being erected at the "Garden Gully Mine" ("Old Battery Group," *see* p. 99), one and a-half miles south of Garden Gully. The Havelock lode was found by T. Creer in 1894*. He was obliged, owing to difficulties in obtaining men, to abandon his find, but shares with the discoverer of gold at the Old Battery (whose name the writer cannot ascertain), the honour of being the pioneer of mining in the Area.

The yield from the Old Battery seems to have been quite insignificant, and the Crown Mine at Garden Gully, which was in operation in January 1895, and continued to yield small returns till 1901, was really the first gold-producer. The Old Battery was, until 1901, the most accessible mill for the treatment of ore raised near Meekatharra.

In June, 1895, a prospector named Bertram reported that the "most likely country" he had traversed on a prospecting trip to "Lake Nabberoo and the Carnarvon Ranges" was that between Nannine and Abbotts.

In May 1896 Meehan, Soich, and Porter had discovered "splendid reefs" on the Pioneer G.M.L., which was then known as the Meekatharra Mine. By the end of the year this and other leases of the Pioneer Group gave employment to about 40 men.

* *Murchison Times*, October 13, 1900.

Between 1896 and 1899, however, mining at Meekatharra waned, till, at one time, J. Savage, who had recently acquired lease "N93," was the only white man on the field. A successful crushing made for him at the Old Battery in 1899, and promising results from the Sirdar Group, near Yaloginda, once more drew attention to the Area. At this time also, R. Oliver and party began successfully to exploit the Haveluck Lode, which has been a fairly consistent producer ever since. In August of the same year the first find of gold on the Paddy's Flat Belt was made by J. McNab on the site of the present Commodore G.M. This was quickly followed by the opening up of the Halcyon Lode just north of the Commodore. Meekatharra now rapidly increased in prosperity, and the "Old Battery" was kept constantly at work on parcels of ore from various leases. In March, 1901, a State Battery at Meekatharra had begun crushing.

B.—Later Development near Meekatharra.

Discoveries on the Paddy's Flat Belt progressed southwards from the Commodore—the Ingliston, Ingliston Extended, Ingliston Consols Extended, and Marmont ore bodies being located successively. The name Paddy's Flat was originally given to the ground now occupied by the Ingliston Consols Extended G.M., on which, in about the year 1901, "Paddy" Donovan and J. Murphy searched vainly for the lode from which the "alluvial" gold in the vicinity had been shed.

Similar difficulty was experienced in locating the Queen of the Hill lode. Although prospects had been obtained in the neighbourhood at least as early as 1902, a definite lode was not proved till 1909.

The discovery in August, 1909, of veins and country similar to those of Paddy's Flat at the Globe G.M.L., two miles further south, is interesting since it indicates that the Paddy's Flat Belt is of considerable length.

C.—Later Development near Garden Gully.

Mining at the north end of the Area, which had practically ceased in 1900, revived in 1909 on the discovery of the Sabbath and Kyarra veins. The former proved unimportant, but the latter showed increasing production to the end of 1914.

D.—Later Development near Yaloginda.

Attention was first drawn to Yaloginda by the discovery of the Sirdar veins by E. Dickson and R. Richards in January, 1899. The Revenue Shoot found by J. Dunn and others at the end of 1904 continued to yield rich patches till the end of 1908, and at about

the latter date the dab of gold in the Black Jack was discovered. Between 1906 and 1910 the Karangahaki G.M. was employing a number of men. At this time also the Batavia, Rocklee, Two Bells, Gibraltar, and many other leases were being actively prospected. In 1908 a townsite was surveyed, and to some extent occupied, at Yaloginda.

In June, 1911, the Karangahaki G.M. closed down and the palmy days of Yaloginda ended. Mining is now dormant at this centre, although there have been occasional small outbursts of activity such as that in June, 1914, at the north end of the Romsey (G.M.L. 891N).

II.—NOTES ON MINING METHODS.

All main shafts, except the underlie shaft of the Mystery G.M.L. at Yaloginda, are vertical-rectangular in form. Most of those on the principal mines are about 10ft. x 4ft. in cross section, timbered throughout, and divided into three compartments: two for hauling, the third for ladder-way, air and water pipes, etc. The Fenian and Ingliston Consols Extended Mines with shafts about 900 feet deep are the deepest mines in the Area.

Hauling on the larger mines is by steam-driven winding engines, and, with the exception of the Queen of the Hill G.M., where self-emptying skips of one ton capacity are employed, cages carry the half-ton trucks singly to the surface. In the smaller mines hauling is done either by a "whip" worked by a horse, or by a windlass; in one case by a whim; and on the Rocklee by a friction winch in connection with the gas engine.

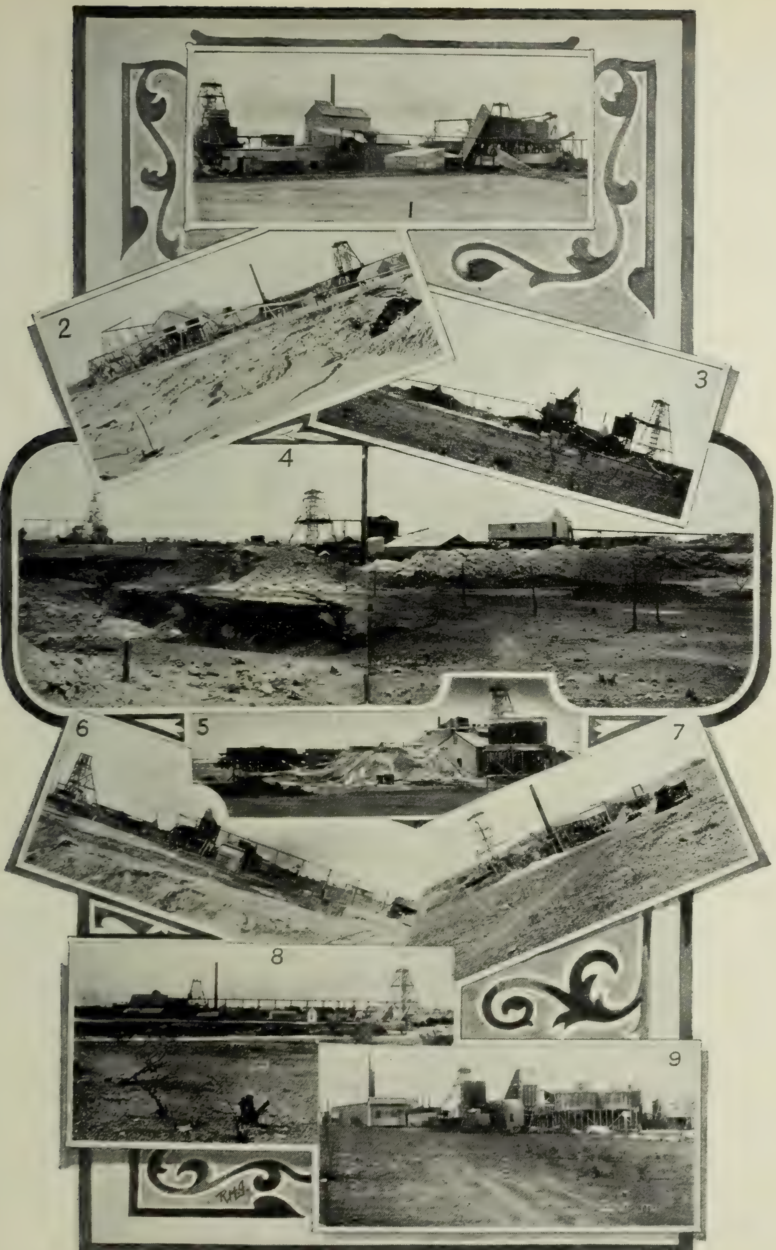
In nearly all the mines the plant is operated by gas-engines, supplied from wood-producers (for detail see Chap. VI.). The local "mulga" and other small trees are satisfactory fuel, both for steam- and gas-engines.

On the Ingliston Consols Extended electric shaft-signalling is installed; in all the other mines the wire knocker-line is still the method employed.

The surface plants of the Kyarra, Commodore, Ingliston, Ingliston Extended, Queen of the Hill, Ingliston Consols Extended, and Fenian mines are electrically lit, light being generated on the individual properties. On the Ingliston Consols Extended, electric light is also provided at all plats and in the cross-cuts of Nos. 4 and 5 levels.

For shaft-timbering, jarrah and oregon pine, for plats, oregon, are usually employed. Below the zone of oxidation, in cross-cuts and drives above which there is no stoping, supports are usually unnecessary. In the timbering of drives preparatory to stoping, either ordinary sets and laths or stulls and laths are used. The heavy

Fig. 9.



Photos.: E. de C. Clarke. Negs. 1330-39.

Surface Plant of the Principal Mines in the Meekatharra Area.

1, Kyarra; 2, Ingliston Consols Extd.; 3, Ingliston; 4, Ingliston Extd.; 5, Fenian; 6, Commodore; 7, Globe; 8, Marmont; 9, Queen of the Hill.

timbers are salmon and morrell gum railed from Geraldton district and costing, landed at the mines, from 4d. to 1s. per running foot, according as the diameter varies from six inches to one foot. For smaller work, such as the timbering of chutes, the local "mulga" is sufficient.

Most of the ore milled in the Area is obtained by overhand stoping and filling. The shallower parts of the ore-bodies are, however, frequently obtained by the open-cut method, the largest open-cut being that of the Queen of the Hill G.M. (Fig. 59).

The filling used, except the little derived from development work, is either tailings or oxidised country obtained by open-cutting.

The vertical distance between levels in the larger mines is about 100 feet. Ventilation depends on the natural circulation through shafts and passes, but in most of the larger mines, air from the compressors is used in the early stages of development.

Except in unequipped mines, lack rather than excess of water has been the main difficulty. The only larger mines on which operations have been at any time hampered by water are the Kyarra, Ingliston Extended, and Marmont Extended. All mines except the Kyarra, Commodore, and Rocklee, equipped with batteries, are supplied with water from Garden Gully by the Mines Water Supply scheme. The original water-level at Meekatharra stood at about 150ft., at Garden Gully at 30ft., while at Yaloginda, where the workings are mainly on the higher ground, it is at about 135ft. Water is or was removed by bailing in the Ingliston, Ingliston Extended, Marmont, Marmont Extended, Globe, and Rocklee; by Cornish lifts in the Kyarra, Pioneer, and Revenue; by a wind-mill in the Halcyon Extended; and by other pumps in the Fenian, Ingliston Consols, Queen of the Hill, and Commodore mines.

Appended is a tabular statement of known facts regarding water in some of the mines and wells of the Area:—

Mine or Well.	Water level below surface.	Approximate height of surface above sea level.	Water per 24 hours, in gallons	Remarks.
	feet.	feet.		
Kyarra*	30	1,590	65,000	
No. 1 Well, Garden Gully	25	1,578	60,000	
No. 3 Well, Garden Gully*	34	1,570	96,000	

* Analyses of water will be found in Chapter IX.

Appended Tabular Statement, etc.—continued.

Mine or Well.	Water level below surface.	Approximate height of surface above sea-level.	Water per 24 hours, in gallons.	Remarks.
	feet.	feet.		
No. 4 Well, Garden Gully	28	1,570	36,000	
No. 5 Well, Garden Gully*	30	1,570	39,600	
Haveluck	170	1,755	..	
Jackson's	51	1,693	..	
New Orleans ..	104	1,713	..	
Commodore* ..	150	1,717	20,000	Country was drained by Commodore before Ingliston had sunk.
Ingliston	200	1,713	..	
Queen of the Hill*	175	1,731	40,000	Great increase in flow when lode is cut at lower levels.
Fenian*	..	1,687	2,000 to 3,000	
Ingliston Consols Extended	..	1,691	1,300	
Marmont*	..	1,637	25,000	Water comes from big spur, not from Main Lode Channel.
Marmont Extended	195	1,681	57,000	100,000 gallons per hour when lode was cut at 195ft. Formerly supplied Ingliston Consols, Fenian, and Marmont G.Ms.
Globe*	130	1,673	3,800	
Karangahaki ..	138	1,588	..	
Mystery	70	1,558	..	
Hornsby	63	1,523	..	
Rocklee*	146	1,633	..	

*Analyses of water will be found in Chapter IX.

III.—TREATMENT OF ORE.

The treatments followed at the Queen of the Hill and Fenian G.Ms. are thus summarised by the officials and are fairly typical of the methods in vogue at the other mines of the Area:—

Queen of the Hill.—Ore is hoisted in one ton self-dumping skips and tipped on to a grizzley. Fines pass through a shaking shoot to a bucket elevator; coarse, after passing the rock-breaker, are similarly elevated to the ore-bin. Thence the ore is fed by the usual type of Challenge suspended ore-feeders to the two pneumatic stampers, which crush in cyanide solution through 4, 5, or 6-mesh screens at a speed of 135 drops per minute. Stamp duty is 80 tons per stamp per 24 hours. The pulp passes to No. 1 leg of the pump and is elevated to a classifying cone. Underflow from this is fed to a 16ft. x 46ft. tube-mill, where a quantity of lime, sufficient to keep the solution alkaline, is added. Overflow together with discharge from grinding pans passes to No. 2 leg of pump and is elevated to the slimes plant. The pulp is discharged in the slimes plant into a large cone, overflow from which passes into two mechanical thickeners, the underflow being again classified in a smaller cone, the overflow of which passes back to the pump, the underflow being fed, together with thickened slime, from the mechanical thickeners to three air agitators in series. Sodium cyanide is added to the air agitators in sufficient quantity to keep up a constant strength in the gold solution. From the air agitators the pulp is collected in an agitator where it is measured and the tonnage estimated by the specific gravity. Thence it is discharged to a lower agitator and then pumped to another, from which it gravitates into a vacuum filter of the ordinary stationary type in which are fitted 60 filter-leaves. After forming and washing, the cakes are blown off into a mixer, pulped with mine water and pumped to the residue dam.

Costs per ton of ore including mining, general expenses, and realisation of bullion for the first five months of 1915 as published locally were:—January 15s. 7d., February 23s. 1d., March 17s. 11d., April 17s. 9d., May 15s. 9d.

Fenian G.M.—Ore is hoisted to the brace in 12cwt. trucks and hand-tipped over grizzleys into the two rock-breakers, whence it is elevated to the ore-bin and fed into the fifteen-stamp mill in the usual way and crushed in cyanide solution. The pulp passes through screening into three Wheeler pans, where amalgamation and sliming take place. The slime passes over two Wilfley tables where the concentrates are collected. These amount to about 2 per cent. of the ore. The pulp is then pumped to the Spitzkasten, whence the coarse is passed to two Wheeler pans for finer grinding—amalgamation takes place in these pans also. The slimes are pumped to five agitating vats (20ft. x 8ft.) and one washout. The unthickened

portion flows to intermittent settling-vats, the thickened to agitators, where cyanide is added. After this the treament is like that described above.

The residues are said to be worth about 2s. 6d. per ton.

During 1915 the Fenian G.M. Syndicate erected a Merton roaster of eight ton capacity for the treatment of concentrates from the various mines of the Area.

Processes in vogue at the other mills in the Area are on the lines of the Fenian treatment. The following points may be noted:—Crushing is performed by ordinary stampers varying in weight from 900 to 1,300 lbs. in different cases. Amalgamating takes place on the plates in the Kyarra, Commodore, Ingliston, Ingliston Extended, Ingliston Consols Extended, Marmont, and Rocklee mills. Cyanidation is employed on the Kyarra, Commodore, Ingliston Extended, and Ingliston Consols Extended mines. In all plants, except the two described, sands and slimes are separated. The sands are treated by the percolation method on the Commodore (four days' treatment), Ingliston Extended (five days'), and Ingliston Consols Extended (six days'). The slimes are stacked for cyanidation on the first and last of these mines.

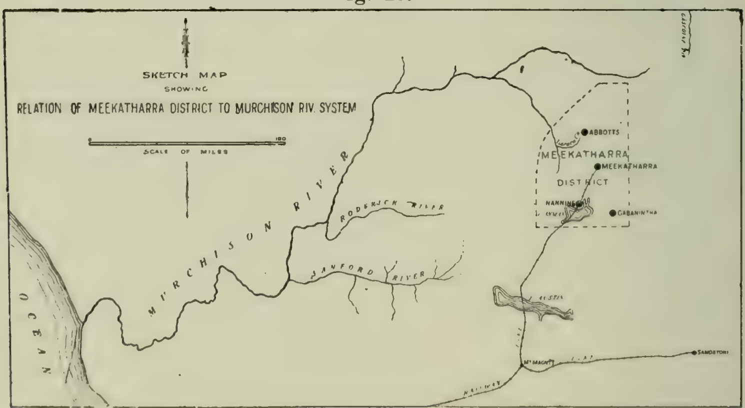
CHAPTER III.

PHYSIOGRAPHY.*

I.—INTRODUCTORY.

It will be seen (Fig. 10) that the western and northern parts of the Meekatharra District drain into the Murchison River, thus forming an area of exterior drainage, whereas the eastern and southern portions, draining into Lake Annean (near Nannine) which has no outlet to the sea, are part of an area of interior drainage. The Meekatharra District is thus on the divide between Jutson's† Salt Lake and North-West physiographic divisions.

Fig. 10.



II.—TEMPERATURE AND RAINFALL.

Meekatharra lies within 3deg. of the tropic of Capricorn, on a tableland about 1,700 feet above sea level, and is 250 miles from the nearest ocean. High temperatures and arid conditions prevail, the District coming within the driest area of the State,‡ with an average annual rainfall (as shown by the following table) of less than 10 inches.

* The writer is much indebted to Mr. J. T. Jutson, who read this chapter in M.S. and made several valuable suggestions.

† G.S. W.A. Bulletin No. 61—"An Outline of the Physiographical Geology of Western Australia," p. 32, etc.

‡ G.S.W.A. Bulletin, No. 61, p. 23.

*Average Monthly Rainfall at Meekatharra.**

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1909	500	*Nil*	*Nil*	302	43	129	25	152	28	*Nil*	12	*Nil*	1,191
1910	*Nil*	46	*Nil*	*Nil*	127	120	164	*Nil*	9	23	*Nil*	109	598
1911	30	25	*Nil*	*Nil*	231	112	82	4	3	*Nil*	*Nil*	*Nil*	487
1912	91	43	72	140	48	*Nil*	97	*Nil*	5	94	21	28	639
1913	489	*Nil*	197	542	*Nil*	59	83	62	27	7	*Nil*	43	1,509
1914	15	49	*Nil*	128	*Nil*	1	112	13	20	26	308	268	940
Averages for six years	188	27	45	185	75	70	94	38	15	25	57	75	894

Temperature Statistics for Meekatharra not being available, and particulars of rainfall having been recorded only since 1909, the following summaries of Rainfall and Temperature Observations at Peak Hill (70 miles north of Meekatharra), Wiluna (120 miles east), and Cue (64 miles south-east) are of interest:—

Average Monthly Rainfall to end of 1910.†

Place.	No. of Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Peak Hill	13	146	120	139	135	97	151	86	71	23	12	21	48	1,049
Wiluna	12	161	121	56	237	124	113	71	47	32	10	12	36	1,020
Cue	16	81	75	55	92	102	157	105	86	42	19	8	38	860

* Supplied by the Commonwealth Meteorologist, Perth. All rainfalls in this and the succeeding tables are in hundredths of an inch. † The Handbook of Western Australia, Perth, 1912, p. 58.

*Average Monthly Rainfall at Peak Hill, Wiluna, and Cue since 1911.**

Station.	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Peak Hill	1911	82	6	*Nil*	*Nil*	186	66	57	5	*Nil*	2	2	20	426
	1912	98	22	68	87	75	*Nil*	120	*Nil*	*Nil*	40	11	14	535
	1913	423	15	187	246	4	93	51	50	13	*Nil*	*Nil*	81	1,163
	1914	13	159	5	133	*Nil*	*Nil*	135	27	18	*Nil*	159	317	966
Wiluna	1911	56	16	3	*Nil*	275	86	17	61	*Nil*	*Nil*	66	96	676
	1912	23	106	295	139	58	*Nil*	84	*Nil*	10	*Nil*	23	7	745
	1913	517	*Nil*	318	177	15	43	58	30	7	*Nil*	*Nil*	231	1,396
	1914	42	41	*Nil*	150	*Nil*	*Nil*	80	5	17	13	205	187	740
Cue	1911	6	*Nil*	3	*Nil*	36	57	57	58	*Nil*	*Nil*	11	81	309
	1912	132	21	44	*Nil*	96	1	85	*Nil*	9	158	20	16	582
	1913	257	*Nil*	129	162	11	92	220	53	25	2	*Nil*	73	1,024
	1914	19	96	3	61	*Nil*	9	146	77	*Nil*	11	189	278	889

* Supplied by the Commonwealth Meteorologist, Perth.

*TEMPERATURE.—Monthly Temperature Means to end of June, 1910.**

Station.	No. of Years.	January.		February.		March.		April.		May.		June.	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Peak Hill	12	99·9	74·5	97·6	73·9	94·1	69·7	85·1	62·2	74·0	53·2	65·9	47·1
Wiluna	9	98·6	71·5	96·4	70·5	93·2	65·2	84·2	57·2	73·9	49·4	64·9	42·7
Cuo	14	101·1	72·2	98·4	71·7	94·3	66·9	85·3	60·1	74·3	51·5	65·6	46·1

Station.	July.		August.		September.		October.		November.		December.		Year.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Peak Hill ..	70·6	50·1	72·6	52·5	74·8	56·5	77·8	59·9	81·3	64·7	85·6	68·6	80·3	61·7
Wiluna	64·1	44·5	70·0	47·4	77·4	52·4	84·6	58·2	93·9	66·6	99·4	72·9	83·8	60·2
Cuo	63·5	40·4	69·2	42·9	76·8	48·0	83·6	53·8	92·9	63·1	98·2	69·5	83·0	56·2

* The Handbook of Western Australia, Perth, 1912, p. 57.

*Monthly Temperature Means since 1911.**

Station.	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
						MEAN MAXIMUM.							
Peak Hill	1911	100·7	100·2	95·9	89·5	74·0	64·5	68·1	69·7	80·3	87·7	98·3	99·9
	1912	104·9	103·3	95·7	87·0	78·1	69·1	66·3	74·6	78·3	87·4	90·9	101·7
	1913	95·3	101·5	91·6	87·3	73·9	67·9	70·0	69·5	78·9	86·3	95·1	97·8
	1914	102·5	101·2	99·7	88·6	79·0	72·8	67·2	75·6	84·2	90·4	89·3	97·7
						MEAN MINIMUM.							
	1911	75·0	74·2	69·7	63·6	52·8	46·0	46·8	47·2	52·8	61·1	68·6	71·6
	1912	77·9	78·9	71·6	64·6	55·8	46·8	46·2	50·0	52·2	60·5	64·9	73·1
	1913	71·9	74·5	70·2	65·5	51·9	47·4	48·6	48·8	54·3	59·6	67·2	70·4
	1914	78·3	75·8	72·7	63·2	55·8	47·6	47·7	53·2	58·6	64·8	65·4	73·0
						MEAN MAXIMUM.							
Wiluna	1911	100·3	97·6	93·3	89·3	73·5	64·1	68·3	67·1	78·5	87·0	98·5	99·4
	1912	105·0	102·6	93·7	84·5	76·8	67·6	65·0	74·2	78·7	87·4	90·1	101·1
	1913	93·7	99·4	89·9	86·3	71·2	67·0	68·1	69·1	77·9	86·5	95·9	97·0
	1914	101·5	100·4	97·6	86·4	76·9	71·4	65·5	74·2	81·5	90·8	89·8	95·8

MEAN MINIMUM.

	1911	72·4	70·4	64·9	56·1	47·6	40·6	41·6	43·2	48·0	57·4	65·3	69·5
	1912	76·4	77·3	68·9	60·4	51·8	40·2	42·5	43·9	48·2	56·5	62·8	70·4
	1913	68·9	70·0	65·5	61·5	45·4	41·7	43·8	45·0	48·2	56·7	64·8	68·9
	1914	75·2	72·9	70·1	57·4	49·9	41·8	43·4	47·5	53·6	62·9	65·1	71·6

MEAN MAXIMUM.

Cue	1911	103·3	100·1	93·5	89·5	73·3	66·2	67·8	68·3	78·7	87·2	96·8	99·2
	1912	104·7	105·4	99·3	88·5	77·1	69·7	64·8	73·8	76·0	85·6	89·6	102·4
	1913	96·5	102·8	91·2	84·2	75·6	70·0	66·7	67·4	78·0	83·6	93·8	95·1
	1914	106·5	100·6	97·3	85·6	78·0	72·0	66·1	75·0	83·3	88·7	86·8	95·6

MEAN MINIMUM.

	1911	74·2	71·4	65·4	60·3	49·5	45·7	45·7	45·3	47·7	55·9	63·0	66·0
	1912	73·7	76·0	70·4	62·4	54·0	45·4	44·8	46·0	48·3	54·9	61·4	69·9
	1913	69·7	73·0	67·1	61·0	50·4	46·9	45·8	45·9	50·4	55·1	62·5	65·6
	1914	77·0	71·7	68·0	57·5	51·3	44·3	45·5	50·0	54·9	61·5	62·2	69·2

* Supplied by the Commonwealth Meteorologist, Perth.

III.—WATERCOURSES.

From the Physiographic Map (Plate III.) and such photographs as Fig. 2, some idea may be obtained of the character of the watercourses. At their source near the divide they are, as a rule, well defined; when they enter the plain country they become diffuse. They carry water only during heavy rain. The work done by the streams in these rare times of flood is considerable.*

The principal streams of the District are: Garden Gully Creek, Tieraco Creek ("Tierdeo" on Pl. III.), and Meekatharra Creek, all of which ultimately discharge into the Murchison River, and the watercourse (for convenience of reference called Yaloginda Creek) which drains into Annean Lake.

As a rule, the beds of these watercourses are cut in detritus. Near their heads outcrops of the underlying rock occur and are particularly frequent in the upper part of Garden Gully Creek. In the lower, diffuse part of the watercourses, detritus, generally sand, of unascertained but probably inconsiderable depth, forms the universal bed.

It will be noticed that the watercourses of the interior system have a north and south course, those of the exterior system an east and west course.

Examples of the capture of portions of the interior by the exterior system are seen in the headwaters of the Meekatharra and Garden Gully Creeks (see Plate III. and also Fig. 11), which evidently belonged formerly to a north and south drainage. Other less notable examples of "piracy" are also to be found. It is thus evident that the basin of the Murchison River is encroaching on the country which drains into Lake Annean. Diversion from a southerly to a westerly course is also apparent in several tributaries of Yaloginda Creek.

IV.—LAKES.

Although one of these features—Lake Annean—occurs at the south edge of the District, the writer has spent only a few hours in its neighbourhood and has no observations of interest to offer on its physiography.

The "lakes" of Western Australia have been described and discussed by Woodward and Jutson.†

V.—HILLS.

The hills of the Meekatharra District are all residuals of erosion, *i.e.*, they are composed of rocks more resistant to weathering than those which form the low-lying country.‡ It is convenient for des-

* *See* for example Woodward, G.S.W.A. Bulletin No. 57, p. 20, *et seq.*

† Woodward, Geol. Mag., 1897, pp. 363–366. Jutson, G.S.W.A. Bulletin No. 61, p. 138, *et seq.*

‡ Jutson, op. cit., p. 158, etc.

criptive purposes to group the hills according to the rock of which they are composed, thus:—

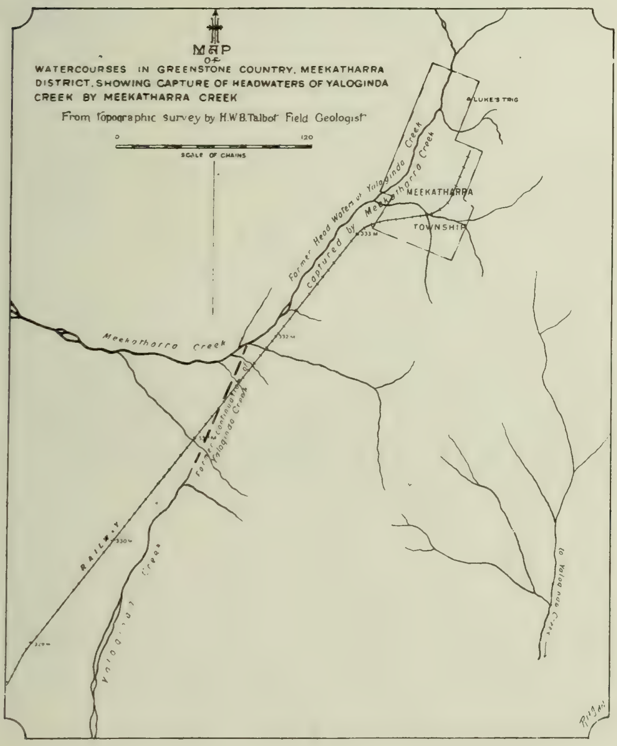
A.—Isolated Hills and Ridges (Island Hills)* in massive greenstones.

B.—Hilly Tracts in schistose greenstones.

C.—"Breakaways" in granite.

D.—Mesas in sedimentary rocks.

Fig. 11.



A.—Island Hills in Massive Greenstone.

The most striking examples of this type are the Barloweerie and Obal Ridges, Murrouli Range and Annean Hill, but a number of less conspicuous island hills also occur. Barloweerie Peaks (2,138ft.) is the greatest height recorded in the District. Reliable heights for the other hills mentioned are not obtainable.

* Mr. J. T. Jutson suggests this anglicising of inselberge in conformity with his adoption of sunklands for senkungsfelder, op. cit., p. 158.

The Island Hills (*e.g.*, Fig. 8) rise with fair abruptness on all sides from the surrounding plain. The ground at their foot is covered with a thin skin of débris, through which in places the under-

Fig. 12.

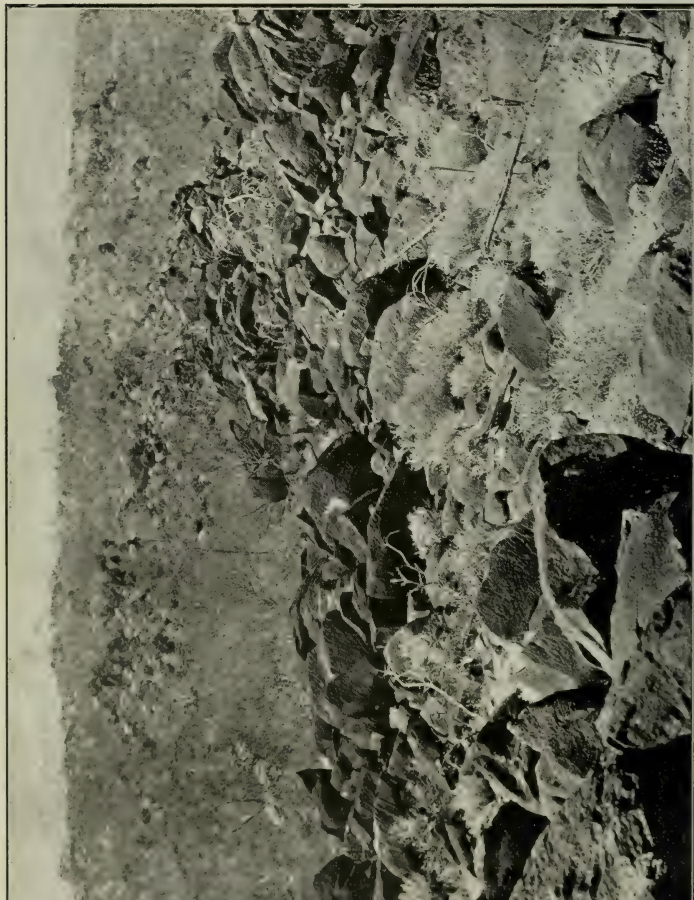


Photo.: E. de C. Clarke. Neg. 1146.

View southwards from Cairn on Barloweerie Peaks (K1). In foreground large boulders of massive greenstone.

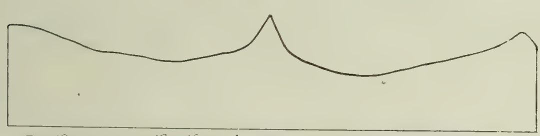
lying rocks outcrop. Their summits (Fig. 12) are devoid of lateritic deposits and covered with boulders, often of very considerable size, of the component massive greenstone.

They differ from the hills considered under the next head in that they rise like islands from the surrounding plain and do not form groups of parallel ridges.

B.—Hilly Tracts in Schistose Greenstones.

A series of parallel ridges occupies the greater part of the surface of the large greenstone "island" on which the mining centres of Meekatharra and Yaloginda are situated (*see* Plate II.). These ridges have a general N.N.E. and S.S.W. trend, corresponding to the strike of the predominant shear planes. The summits of the ridges, which frequently coincide with the outcrops of "jasper bars," rise to about 1,800 feet above sea-level and are seldom more than 100 feet above the intervening valleys. The summits show a gradual, constant decrease in height, coming south from Meekatharra to Yaloginda, indicating that the original land surface sloped from north to south. Except where a protecting cap of ferruginous laterite causes a sudden and marked increase in grade, giving an approach to the mesa-form, the sides of the ridges slope gently down to the watercourses, so that in cross section the valleys are broadly U-shaped (Fig. 13).

Fig. 13.



Section across two typical valleys in Hilly Greenstone Tract
From topographic survey by H W B Talbot — Field Geologist
Vertical Scale 0 — 200′
0 — 20′ Horizontal Scale

In some places the formation of water-gaps in the ridges by small subsequent watercourses may be seen in progress.

C.—"Breakaways" in Granite.

"Breakaways" are lines of cliff, seldom exceeding 50ft. in height, separating a lower from an upper, more dissected plain, of which they form the edge. The term is, however, frequently applied to any low cliff, whether forming the side of a valley or rising above a plain. Breakaways are considered to originate from the under-cutting, partly by wind-action, of a soft decomposed rock which is protected by a skin of secondarily hardened material.*

* For further discussion *see* Woodward, G.S.W.A. Bulletin No. 57, p. 20, *et seq.*

A comparison of the physiographic map (Plate III.) with the general geological map (Plate II.) shows that generally "Breakaway Country" occurs in the northern portion of the granitic area.

D.—Mesas.

Mt. Yagahong (Figs. 1 and 14) and Table Top Hill (Fig. 15), are typical mesas. As mentioned in Chapter IV. these hills are composed of flat-bedded sediments. Their outline is distinct from that of any other type of hill in the District, but in a few places isolated remnants of breakaway country and the greenstone ridges, where protected by laterite caps, have the mesa form.

Fig. 14.

Photo.: E. de C. Clarke. Neg. 1220.

Mt. Yagahong. Distant view from north.

Fig. 15.

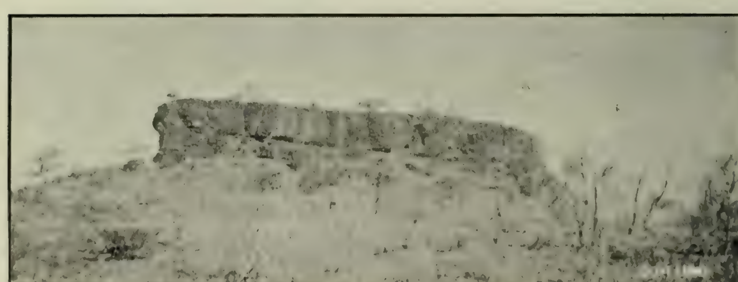


Photo.: E. de C. Clarke. Neg. 1215.

Table Top Hill, from west.

VI.—PLAINS.

As indicated on the physiographic map, the main development of plain-country is in the basin of Tieraco Creek, and in the south-eastern portion of the District.

Fig. 16.

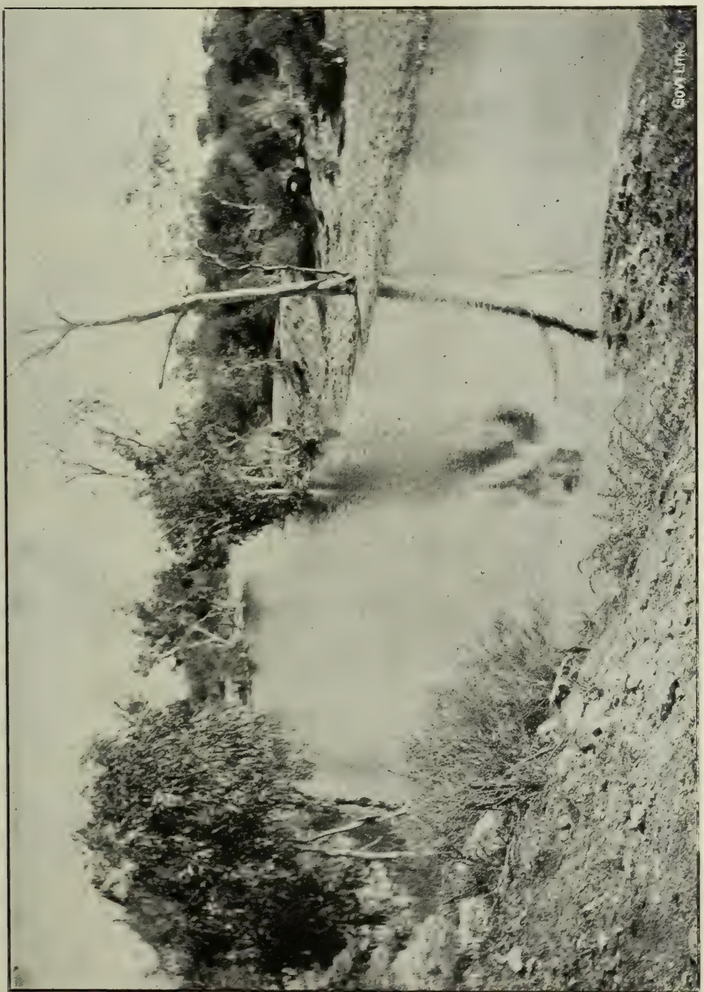


Photo.: E. de C. Clarke. Neg. 1399.

Pool on Garden Gully Creek above Kyarra G.M., after three months' drought. The white rubble on the left foreground is travertine.

The plains are generally covered with a uniform growth of "mulga," and, after good rains, carpeted with a luxuriant growth of grass or wild flowers. Outcrops are very rare. The water-

courses, except the largest, are ill-defined; swamp-gums, which relieve the monotony of the mulga-covered plains, grow along most of them.

The surface of the plains being, apparently, everywhere underlain by a hard-pan of almost impervious "cement" becomes covered, after heavy rain, with a shallow sheet of water, which, excepting that which remains in hollows as pools, flows slowly away in the direction of main drainage. Some of the pools in the larger watercourses may survive several rainless months (Fig. 16).

Generally (compare Plates III. and IV.) the plain-country occurs in the granite areas. An exception is the plain lying to the south and west of Garden Gully, which is composed of greenstones, apparently similar to those occupying the hilly tracts. This greenstone plain merges in three directions through fairly narrow "straits" into areas of granite plains.

VII.—SUMMARY.

The Meekatharra District is situated on the Divide between areas of exterior and interior drainage (Jutson's North-West and Salt Lake Divisions). The hills occurring on greenstone areas have a north and south trend, those on granite areas are disposed quite irregularly. Two mesas also occur. The drainage channels belonging to the exterior system have a westerly, those of the interior system a southerly course. The exterior system is encroaching on the interior.

The summits of the ridges in the greenstone country and of the rough granite areas have a maximum height of between 1,850 and 1,900 feet, while the elevation of the plain-country ranges between 1,700 and 1,800 feet. According to Jutson* there may be distinguished in the great plateau of Western Australia the "old plateau," which represents, approximately, the level of the country at the beginning of the present physiographic cycle, and a "new plateau" which is now being formed out of the old plateau by arid erosion. In the Meekatharra District then, the country shown as plain (Plate III.), together with the smaller patches of plain-country not indicated, would be regarded as portions of the new plateau, while the summits of the greenstone ridges, granite hills and breakaways represent approximately the level† of the old plateau.

In the absence of reliable heights for the island hills (except Barloweerie Peaks, 2,138ft.), it must remain doubtful whether these also are portions of the old plateau or are monadnocks which rose above it before the beginning of the present cycle of erosion.

* G.S.W.A. Bulletin, No. 61, p. 20, etc.
† The gradual decrease in the height of the greenstone ridges coming south shows that there was in this part of the old plateau a gentle slope to the south.

CHAPTER IV.

GENERAL GEOLOGY.

I.—INTRODUCTORY.

A.—Geological Position of the District.

The chief gold-bearing region of Western Australia may be compared to a sea of granite in which islands of "greenstone" are scattered. The chief mining centres are on two lines of greenstone islands, the eastern running from Norseman through Coolgardie, Kalgoorlie, Mulline and Sandstone to Meekatharra, the western from Ravensthorpe through Southern Cross, Mt. Jackson, Mt. Magnet, and Austin to Day Dawn and Cue.* These two belts were recognised by Mr. H. P. Woodward in 1895.†

B.—Main Features of the District.

On the general geological map (Plate II.) the rocks of the District are shown to be acid igneous (granites and porphyries), basic igneous and metamorphic (greenstones), and sediments.

Two large greenstone "islands"—the northern bearing Abbott's and Garden Gully Mining Centres, the southern Meekatharra, Yaloginda and Nannine Centres—are separated by a "strait" of granite. A number of smaller "islands," such as Annean Hill, have been recognised. Resting indifferently on granite or greenstone are small patches of sedimentary rocks.

C.—Co-ordination of Field-work and Petrology.

Individual rock-specimens and special geological occurrences are frequently quoted in this and succeeding chapters, but details favourable or unfavourable to the conclusions arrived at cannot be fully given. It is well, therefore, to describe the method by which the classification and mapping of this report were accomplished.

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* Recent advances in the knowledge of the Geology of Western Australia by A. Gibb Maitland. Austra. Ass. Adv. Sc. 1907. Plate I.

† Mining Handbook to the Colony of Western Australia, 2nd Edition (Perth, 1895) p. 38.

The 800 or more specimens obtained during field-work were catalogued and arranged by the writer in camp according to megascopic characters, and typical examples of every variety of rock thus distinguished were finally chosen for further examination.* From the 600 or more specimens so selected, about 180, regarded after careful scrutiny by Mr. Farquharson and the writer as representative of all important varieties, were studied in detail by the former, who then drew up a tentative classification embracing all varieties recognised as a result of his work. The catalogues made in camp were now searched for additional examples of these types from other localities, and the field-distribution of Mr. Farquharson's varieties was mapped.† The relationships, suggested by petrological study, of all rocks found in the Area were thus contrasted with their field-relationships, and the new difficulties and contradictions which this comparison produced necessitated much additional microscopic work and a short visit to the field. Some of the difficulties were solved; some have remained unsolved. The final results are set forth in this and the next three chapters.

II.—ACID IGNEOUS ROCKS.

A.—Granite.

In the country immediately south of the District two main types of granite have been recognised‡—a hornblende-granite which frequently contains auriferous veins particularly near its contact with the greenstones, and "a hard porphyritic muscovite variety which generally occurs in the form of magmatic intrusions" into the hornblende granite, and weathers into "more or less rounded masses having the appearance of piled blocks."

Granitic rocks occupy about 1,600 square miles in the Meekatharra District. Those coming within the Area are of no economic importance, and therefore little attention was given them. Two types were recognised but whether they are merely phases of the same magma or represent two distinct intrusions was not determined.

1. *Southern Cross Type.*

General Petrology.—This rock, so named from its similarity to the granite near Southern Cross,§ is a biotite-microcline granite.‖ Unlike the Meekatharra granite it is only occasionally sheared, has a prevailing yellow-brown colour, contains pegmatite dykes, and with it are in places associated gold and copper ores.¶

* The writer's views on the District's geology at this stage were those given in G.S.W.A., Ann. Rep. 1913, pp. 25, 26, and 1914, pp. 23, 25, and Journal Chamber of Mines of W.A., April, 1915, p. 63.

† The writer's views, modified by this work, are given in G.S.W.A. Ann. Rep. 1915.

‡ Woodward, G.S.W.A., Bull. No. 57, p. 19, etc.

§ G.S.W.A., Bull. No. 49, p. 67.

‖ Petrological notes are given fully in chapter VII.

¶ Near the Chunder Loo G.M., outside the Area and not examined by the writer.

Distribution and Relation to other Rocks.—The Southern Cross granite is shown (Plate IV.) occupying a small area west and south of Yaloginda (*see* also Fig. 4). Within the Meekatharra Area it was noted as far north as the 17-mile post on the Telegraph Line, beyond which the boundary between granite and schist is obscured until, some distance north of Meekatharra Creek, granite of the "Meekatharra type" is found. Detailed work further west here might show the true relation between the two types, and, since conglomerate at the Haveluck group, north of Meekatharra, contains boulders of Southern Cross granite, it is probable that this latter type would, in the west, be found extending further north.

No evidence has been collected as to the character of the granite lying east of Meekatharra.

Where in contact, neither greenstone nor Southern Cross granite show unusual weathering or alteration—indeed the greenstone is harder and fresher as the granite is approached. Many tongues both of normal and of pegmatitic granite occur in the schists near the contact, generally parallel to the shear planes, and lenticular greenstone inclusions sometimes several chains long are found in the granite even some distance from its edge.

2. *Meekatharra Type.*

Petrology.—This is a microcline-biotite granite showing both in its almost universal foliation when viewed in the field or in hand-specimens, and in such microscopic features as strain-shadows in the quartz, breaking, bending, and granulitization of felspar and quartz, that it was subjected to very considerable shearing forces. Such varieties as $\left[\frac{1}{130}\right]$ * (near the 57-mile post on the Peak Hill road), which show no trace of shearing, are seen in the field to occur in small patches (which have escaped dynamic metamorphism) amongst the normal, strongly foliated granite of Meekatharra type.

Distribution and Relation to other Rocks.—This type traverses the Area in a general N.E. direction, parallel to the prevailing strike of the country, as a band† three miles or more in width, and, except the ill-defined patch of Southern Cross type, constitutes all the granite of the Area.

Though but one specimen has been microscopically examined, the granite to the north of the Area in the neighbourhood of the Peak Hill road has all the appearance in mass and hand-specimens of the Meekatharra type.

The Nannine granite also agrees microscopically with the Meekatharra type but carries auriferous veins, said to pass without inter-

* The numbers quoted thus are of rock specimens examined by Mr. Farquharson.

† A small area of this granite is mapped (Plate IV., Sheet A.) about 2½ miles W.S.W. of the 29-mile post, Garden Gully road. No evidence of the connection of this occurrence with the main mass could be found in the field.

ruption from greenstone to granite and to be auriferous in both rocks. However,

"most of the reefs in the granite at Nannine appear to have been of low grade."*

Some abandoned workings west of Nannine, near the 153-mile post on No. 2 Rabbit Proof Fence, from which some ore has apparently been taken, are on small veins in Meekatharra granite $\left[\frac{1}{128}\right]$.

The most important veins at Quinn's—a short distance south of the District—occur in "granite schists" (Gibson, *loc. cit.*, p. 41), presumably a gneissic granite of the same type.

Within the Area none of the many quartz veins in the Meekatharra granite appear to be auriferous, though they must have been often "tried." A sample of quartz was taken by the writer along

Fig. 17.

Photo.: E. de C. Clarke. Neg. 1223.

Contact between Schist and Kaolinised Meekatharra Granite, three miles east of 57-M.P., Peak Hill Road.

the strongest of the veins found about $1\frac{1}{2}$ miles E.N.E. of the 27-mile post on the Garden Gully road (Plate IV., Sheet A), and was submitted for assay (Lab. No. 7118), but yielded no trace of gold.

Except along its margins the Meekatharra granite forms rough "breakaway country" interspersed with patches of rounded boulders usually of considerable size (Figs. 5 and 6).

In contrast to the Southern Cross Granite, the boundary between the Meekatharra granite and the greenstones is usually very ill-defined. Both rocks are highly decomposed along their margin

* Gibson, G.S.W.A., Bull. No. 14, p. 53.

—the granite being completely kaolinized for a chain or more and the greenstone altered to a white kaolinic mass hard to distinguish from kaolinised granite. Very rarely a sharp contact like that in Fig. 17 (in which case the weathered granite was shown to have the microscopic characters of the Meekatharra type) was observed.

3. *Economic Importance.*

As the preceding remarks indicate, the granites of the Meekatharra Area appear to contain no deposits of economic value and may be ignored by the prospector, although, further afield, similar rocks of both types carry auriferous veins.

B.—Porphyry.

The acid dykes of the Area may be arranged for description in four groups. This arrangement is based mainly on the relation of the dykes to gold deposits. Owing to its highly weathered state nothing is known of the minute characters of one of these groups, but detailed examination of many specimens of the other three shows that probably all of them and the Meekatharra granite are of common magmatic origin.

1. *Paddy's Flat Type.*—Albite-quartz porphyries.

(a) *Paddy's Flat Dyke.*—This dyke extends almost continuously from the Gwalia Extended Group at the south end of the Paddy's Flat Belt to the Ingliston North G.M.L. Owing to ease of weathering and development of covering "cement" it is never recognizable at the surface (though outcrops of bleached "greenstone" are often mistaken for it), but is shown on Plates IV. and XIII. approximately as it would outcrop. It is dislocated in several places by small faults and has been broken by a dolerite dyke near the Ingliston United G.M.L. The gap in the Fenian and Ingliston Consols Extended Leases is due to the injection having failed to reach so far as the present surface, but at the lowest levels of these mines an almost continuous dyke of porphyry is found. (*See* Plates XVI. and XIX.).

To depths of two or three hundred feet the Paddy's Flat porphyry is decomposed to a white kaolin (often, but not invariably, seamed with quartz veins (Fig. 18)), in which small grains of quartz can almost always, and flakes of mica quite frequently, be detected. Below the weathered zone it is a very hard, tough, white, flinty, semi-translucent rock, strongly cross-jointed (Fig. 19). Occasionally it has felspar phenocrysts or crystals of pyrite or arsenopyrite.

The Paddy's Flat porphyry is often closely associated with auriferous veins and "formations." The fuller discussion in Chapter

Fig. 18.

Photo.: E. de C. Clarke. Neg. 1420.

Weathered Porphyry in 300ft. level, Ingliston Extd. G.M. Quartz veins more evident than in fresher rock (cp. Fig. 19).

VI. may be summarised by stating that the porphyry injection was earlier, but very little earlier, than gold injections.

(b) *Yalogind Dyke.**—Porphyry outcrops at intervals from the neighbourhood of the Sirdar Group to the southern boundary of

Fig. 19.

Photo.: E. de C. Clarke. Neg. 1417.

Unweathered Porphyry in north end, No. 4 level, Ingliston Consols Extended G.M. Porphyry is bordered by lode.

the Area—a distance of nearly five miles. These outcrops being nearly in alignment are probably points on one dyke.

A few small outcrops just east of the "Stockholm G.M.," two and a half miles north-east of the Sirdar, are a highly decomposed acid intrusive probably of the same type.

* Further detail regarding this and the other dykes will be found in Chapter VI.

Petrologically the northern portion of the Yaloginda dyke (47d. and $\left[\frac{1}{109}\right]$) resembles the Paddy's Flat rock. Specimens from the southern end ($\left[\frac{1}{108}\right]$, $\left[\frac{1}{118}\right]$, $\left[\frac{1}{119}\right]$, $\left[\frac{1}{291}\right]$), while they resemble the Paddy's Flat type, show some of the peculiarities of other types described below.

In field-occurrence the Yaloginda differs from the Paddy's Flat dyke in being in places resistant to weathering and so forming hillocks (Fig. 20).

Fig. 20.

Photo.: E. de C. Clarke Neg. 1216.

Outcrop of Porphyry half a mile south of Yaloginda.

Economically it is not of proved importance, but $\left[\frac{1}{109}\right]$ in shaft 25 (Kelpy Group) lies close to a rich "alluvial" patch, the parent vein of which has not been much explored. In its southern part the Yaloginda dyke is associated with quartz veins, often of large size (Fig. 21). These have not been found to yield gold, but from the fact that the dyke here shows affinities to the Halcyon type, further search in these parts may prove portions of it to be gold-bearing.

(c) *Maranui Dyke.*—This outcrops about a quarter of a mile east of the Karangahaki Belt, and has been followed for about that distance in a southerly direction, beyond which the presence of boulders of tourmaline-bearing quartz indicates its probable extension towards Rhen's Prospecting Area. Petrologically it and the Paddy's Flat Dyke are very similar, but in the presence of radiating fibres of actinolite and biotite it shows affinities to the southern part of the Yaloginda dyke, which it also resembles in field occurrence, some specimens from the surface being as hard and fresh as the Paddy's Flat dyke is at depths of 400 feet or more. So far as known, the Maranui Dyke is not associated with any auriferous deposits.

(d) *Northern Dyke.*—East of the 57-mile post on the Peak Hill road two small greenstone islands occur. Specimen $[\frac{1}{112}]$ from the margin of one of these appears to be a felspar-porphyry with felspar phenocrysts and numerous actinolite needles, an increase in the number of which transforms the rock into an actinolite-amphibolite or hornblendite. This rock the Petrologist considers more closely allied to the Paddy's Flat than to any other porphyry, and, occurring as it does on the margin of the Meekatharra Granite, it is evidence that the latter and the various porphyries have a common origin.

Fig. 21.

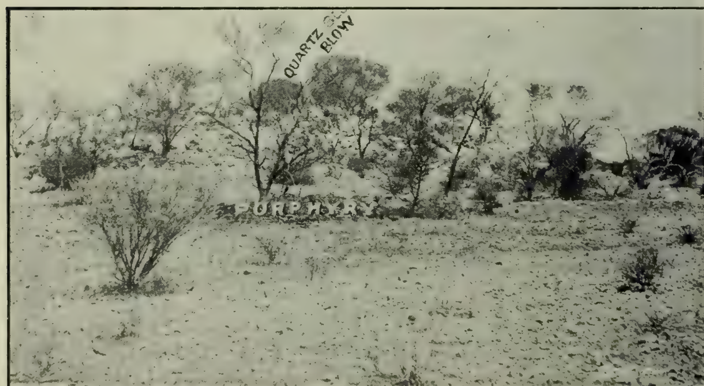


Photo.: E. de C. Clarke. Neg. 1217.

Outcrop of Porphyry and Quartz Blow one mile south of Yaloginda. Porphyry outcrops also on the far side of this quartz blow.

2. *Pioneer Type.*—Granite- and true quartz porphyry.

The Pioneer dyke occurs in the Pioneer Group a short distance east of Meekatharra and is mapped on Plates IV. and XIII. (Sheets 1 and 3). It outcrops in its northern part.

A micacised, fine-grained porphyry verging on granite-porphyry, a coarse granite-porphyry, and a true quartz porphyry, with intermediate types, are all represented in this dyke.

Economically it is of importance, being connected with some of the first-discovered gold-bearing veins of Meekatharra. These (*see* further Chapter VI.) are regarded as ultra-acid portions of the porphyry which were extruded just before its final consolidation.

They cut obliquely through the porphyry and neighbouring greenstones and yield nearly all their gold from the parts which lie in the greenstone.

Fig. 22.

Photo.: E. de C. Clarke. Neg. 1413.

Halcyon Porphyry Dyke in 25ft. level off shaft M. (G.M.L. 425N.) Shows quartz veins of dyke ending against schist wall.

Near the 68-mile post on the Peak Hill road occurs [$\frac{1}{103}$] probably a marginal phase of the Meekatharra granite, showing affinities with other types and a marked resemblance to the Pioneer porphyry. It is thus a link between this rather distinct rock and the other acid intrusives.

$\left[\frac{1}{292}\right]$ from scattered boulders near the racecourse about three miles north of Nannine is very similar both mega- and microscopically to $\left[\frac{1}{103}\right]$ except that it shows no quartz phenocrysts. From their field-position the boulders would appear to indicate a dyke running northwards from the granite at Nannine.

3. *Halcyon Type.*—Chloritised albite porphyry with auriferous cross veins.

None of the dykes mentioned under this head are found outcropping.

(a) *Halcyon Dyke.*—This dyke has been traced with fair certainty for about half-a-mile from the north end of the Commodore G.M.L. to that of the Halcyon Extended Lease. The highly kaolinised rock of the New Orleans Group further north, though on the line of this dyke, lacks its most distinctive features.

The Halcyon dyke varies from a very acid phase of a quartz-porphyry magma $\left[\frac{1}{101}\right]$ through a platy albite-porphyry (346c) to a chloritised albite porphyry $\left[\frac{1}{08}\right]$.

From their field positions the Paddy's Flat and Halcyon dykes might well be parts of the same intrusion, but, petrologically, they differ considerably. An additional difference is that the Halcyon Dyke carries small auriferous quartz veins which usually end against the "greenstone" walls of the dyke (Fig. 22).

(b) *Beverley Dyke.*—On the map this figures rather largely just west of Meekatharra (Plates IV. and XI.). It is found in the old Beverley workings and at the north-west corner of Meekatharra townsite. Its possible northern and southern extensions occur respectively in a small shaft near the old Rifle Range and in a shaft near the 21-mile post on the Nannine road.

So far as known, the gold occurs in small veins in this, as in the Halcyon, dyke. The rock is too decomposed for microscopic examination and there is therefore no evidence as to its real affinities.

(c) *Romsey Dyke.*—This dyke, which traverses the Romsey Group near Yaloginda, and is responsible for all the gold won in that neighbourhood, agrees in petrology and mode of gold occurrence with the Halcyon Dyke.

The Romsey Dyke possibly extends northward to the "cement patch" (*see* Chapter VI., p. 199).

(d) *Hornsby Dyke.*—Probably the highly weathered acid intrusive in the Lewes Castle and Hornsby Groups is of the same type as the Romsey Dyke and is connected with it.

4. *Haveluck Type.*—Petrology unknown. Gold carried both in felspathic and quartzose portions, which seems sufficient reason for separating this type from the others.

(a) *Haveluck Dykes.*—These, occurring on the Haveluck Group, are described in Chapter VI., p. 108. No specimen fresh enough to repay microscopic examination can be obtained.

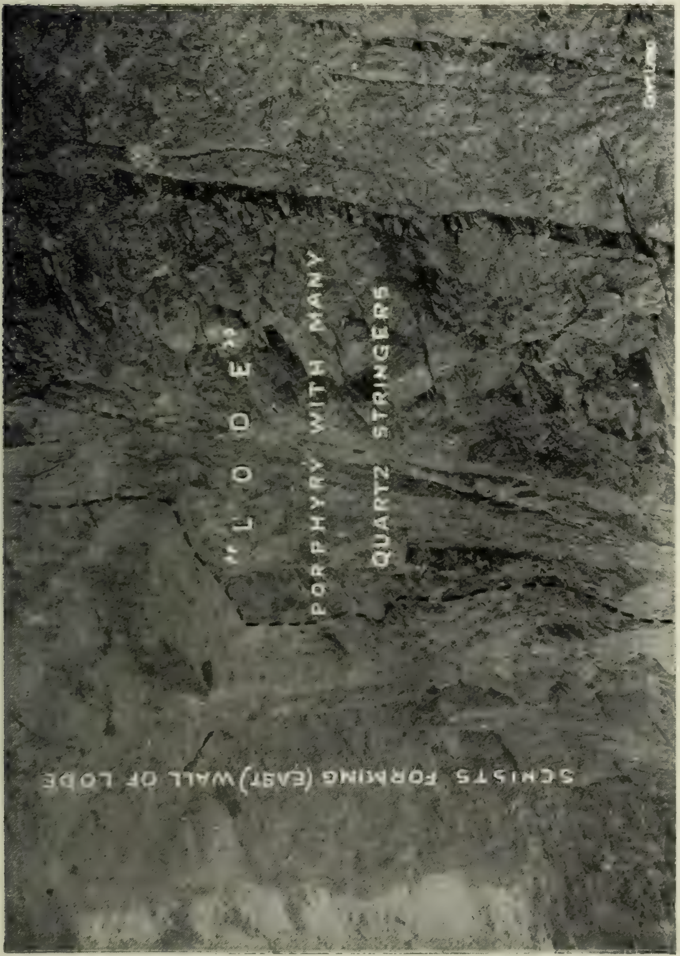


Fig. 23.

Photo.: E. de C. Clarke. Neg. 1421.

Romsey Porphyry Dyke in open cut (G.M.L. 891N).

(b) *Ralph's Patch Dykes.*—These lie about a quarter of a mile east of the Haveluck dykes, with which they are grouped from their nearness in the field more than any other reason.

(c) *Jasper Star Dykes.*—These are much decomposed apparently intrusive rocks. They lie a little east of the Sabbath Group and are the only acid intrusives (except two outcrops, probably of porphyry, 50 chains west of the 29-mile post and 120 chains W.S.W. of the 28-mile post, Garden Gully road) found north-west of the Meekatharra granite. No information could be obtained as to their relation to the gold-occurrence in the vicinity.

Fig. 24.

Photo.: E. de C. Clarke. Neg. 1424.

Havcluck Porphyry below 50ft. level near North Shaft (G.M.L. 236N).

5. *Effects of the Intrusions.*—The contact-metamorphic effect of the porphyries and those of the veins which followed shortly after their intrusion cannot be distinguished and are considered in the next chapter.

6. *Source.*—The porphyries of the Meekatharra Area, though differing from place to place, show a variety of intermediate types and it is reasonable on the score of their chemical composition to suppose that they and the Meekatharra granite have a common origin. None of the dykes, except the Ralph's Patch, can be proved in the field to join the granite—owing to the obscurity of the granite boundary itself such proof would be impossible—but their orientation makes such a connection highly probable.

The absence in the porphyries of the shearing which is so marked in the granites may seem an insuperable objection to the idea that they come from the same source as the granite. If, however, the intrusion of the dykes was followed by a lull in earth-movements, then, after their consolidation—a comparatively rapid process—their compactness, the general parallelism of their long axes to the direction of shearing, and the fact that they were surrounded by readily yielding (because already-sheared) rocks, would render them immune from shearing.

III.—GREENSTONES.

In the Cue district Mr. H. P. Woodward* distinguishes two classes of "greenstones"—older chloritic schists and amphibolites which are traversed by younger dykes of dolerite, gabbro and andesite. He regards the older greenstones as older than the porphyritic granite (Southern Cross type of this Bulletin).

The "greenstones," mapped as one rock-series on Plate II., but subdivided in the more detailed maps, include unmetamorphosed basic igneous rocks, both dyke, flow and fragmental, and a number of more or less metamorphosed rocks—all originally basic or ultra-basic igneous.

A.—Unaltered Igneous Rocks.

1. *Basaltic Dolerite.*—This rock, found only in some workings of the Paddy's Flat Belt, is a mica-hornblende dolerite. † Above water-level it is converted to a reddish, spheroidally-weathering clay in which remains of phenocrysts can be seen. It is thus usually possible to distinguish the weathered dolerite from other "greenstones"—a matter of practical importance, for the dolerite is never auriferous, and, below water-level, is an expensive rock to mine. Ignorance of these facts no doubt led to the sinking of

* G.S.W.A., Bull. No. 57, p. 42.
† Farquharson, G.S.W.A. Bull. No. 43, p. 73.

the old main shaft of the Ingliston Extended G.M. in the dolerite, and to a good deal of fruitless prospecting in the same rock in the Ingliston South Extended and United leases.

A fuller account of the distribution of this rock is given in Chapter VI. It is sufficient to note here that it is best developed in the Ingliston Extended G.M. where it is an almost vertical dyke with a N.E. and S.W. course, and that it can be traced on the same general course nearly half-a-mile further north, its northernmost occurrence (61d) being gabbroid in character. South of the Ingliston Extended it turns sharply west, cutting across the Paddy's Flat porphyry dyke and lode-channel, and then, resuming its southwesterly course, may be identified at intervals for half a mile further.

The basaltic dolerite is the youngest of the deep seated rocks. It has been subjected to no shearing or other earth-movements and is later than the gold-bearing solutions.

In general appearance, microscopic structure, and relation to other rocks and to ore deposits it is exactly like the basaltic dolerite of Sandstone,* of the Great Fingall Mine and of the Hidden Treasure Mine at Cue.

The writer is informed by Mr. H. W. B. Talbot that dolerites very similar to this rock are found frequently from Peak Hill northwards intruding rocks of all ages, including the Oakover limestones. The latter rocks occur only in the valleys of the Oakover River System, the high land being occupied by beds of the Nullagine series (*see* below, p. 76), and appear to rest unconformably on the Nullagine beds. The Oakover beds would thus appear to be estuarine deposits quite possibly of Tertiary age. It thus seems likely that the intrusion of the Ingliston Extended dolerite took place in tertiary or even later times.

2. *Norite.*—The summit of Barloweerie Peaks (Fig 12) is composed of norite (for further description *see* Chapter VII.). A similar rock has been described from Cue.† Norite dykes have been recognised in various parts of the State, the typical locality being Norseman, where they are said to be the "most recent" of all rocks in the district.‡ No evidence as to the relation of the Barloweerie norite to neighbouring rocks has been obtained.

3. *Volcanic Series.*—Basaltic and andesitic fragmental rocks and flows.

Distribution.—This series lies immediately east and south-east of the Paddy's Flat Belt, stretching in a narrow band from near the Globe G.M. to the neighbourhood of the Macquarie Lease, and, like

* G.S.W.A., Bull. No. 62, pp. 34–40.

† Gibson, G.S.W.A., Bull. No. 14, p. 15; and Simpson, G.S.W.A., Bull. No. 29, Part II., p. 51.

‡ Campbell, G.S.W.A., Bull. No. 21, p. 24.

other rocks of the Area mapped almost solely from outcrops, its boundaries can only be vaguely determined.

Petrology.—(i.) *Andesitic and Basaltic Flows.*—These show much variety in state of preservation, some outcrops being very weathered, others hard and fresh. They may be broadly described as fine-grained, phenocrystal flow-rocks, ranging from basalt to augite andesites. Hand specimens do not differ markedly in appearance from the doleritic greenstones described below.

(ii.) *Fragmental Volcanics.*—These vary as much in state of preservation as the flow-rocks, and are volcanic breccias and crystal tuffs containing fragments up to half an inch in length of the flow-rocks and also of the older greenstones. In hand specimens the fragmental nature of the rock is at once evident.

Flow- and fragmental rocks occur together in alternating bands. The best example is about 1¼ miles E.S.E. of the Gwalia Extended G.M.L., where bands of fresh augite andesite and of tuffs outcrop.

Age and Relation to other Rocks.—The volcanic series, judged only by its general freshness and unmetamorphosed character, would be regarded as recent compared to the greenstones yet to be described. Petrologically it shows little affinity to the basaltic dolerite of which it might otherwise be regarded as the surface equivalent. There are reasons (*see* below, p. 73) for correlating it with sediments of possibly Devonian age.

B.—Metamorphosed Igneous Rocks.

1. *Of Doleritic Origin.*—Except the comparatively small areas occupied by the peridotitic greenstones, and those described above, all the greenstone country in the District is composed of rocks of this subdivision. It must be noted, however, that considerable expanses mapped as metamorphosed dolerites are covered with superficial deposits and yield no information as to the type of greenstone obtaining there.

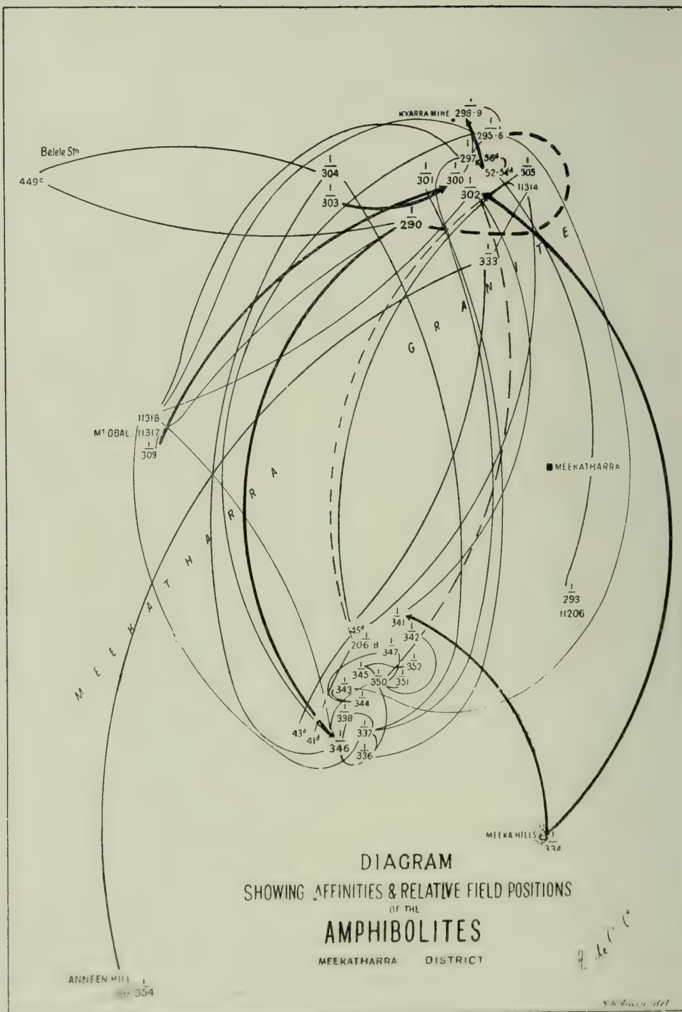
So much does the intensity of metamorphism vary in the rocks of this subdivision that specimens might easily be chosen which are apparently very unlike. However, when the complicated interrelationships of the varieties are considered* (Chapter VII.) it is evident that the rocks have a common origin.

Similarly the "greenstones" of Sandstone and Hancocks owe their differences to varying intensity of shearing and are derived

* Fig. 25 is an attempt to show graphically the affinities of the doleritic greenstones (excluding those of Paddy's Flat). The specimen-numbers are shown approximately in their field positions. Heavy lines lead from those least altered from the original and end in arrow heads against their derivatives. Thin lines connect similar rocks about equally metamorphosed. Broken lines indicate uncertainty. It will be found that all the rocks, however diverse, are ultimately connected.

from a single rock-mass of which the least altered parts are exactly similar to the least altered of the Meekatharra greenstones (Group (a) below)* In the Cue district also are large developments of

Fig. 25.



uralitised zoisitised dolerites,† from which it seems probable that the more schistose greenstones have been derived.

* G.S.W.A., Bull. No. 62, p. 19, *et seq.*
† G.S.W.A., Bull. No. 29, Part II., pp 51-52.

A comparison of the Kalgoorlie and Meekatharra greenstones and further reference to the correlations suggested above are given in Chapter VII.

Although it is impossible to draw many definite boundaries between the various dolerite derivatives, the following classification has been adopted in mapping, and the varieties can usually be distinguished without the aid of the microscope:—

(a) Uralitised, zoisitised dolerites.
(b) Actinolitic, zoisitic rocks.
(c) Massive amphibolites.
(d) Hornblende schists (Batavia schists).
(e) Sheared amphibolites (Yaloginda schists).
(f) Sheared chlorite-felspar rocks (Kyarra schists).
(g) Sheared porphyritic chloritic dolerites (flecked schists).
(h) Some talc-chlorite-carbonate rocks.
(i) Fuchsite-quartz-carbonate rocks.

(a) *Uralitised, zoisitised Dolerites.*—These, which are the least altered from the original rock of the series, are found in several places, generally on the island hills (Chapter III., p. 43), where, as at Mt. Obal, sheared rocks [**11318**] are found to pass along their strike into the uralitised dolerites [**11317**], $\left[\frac{1}{309}\right]$. These massive rocks are also flanked by sheared varieties, and in one locality (Garden Gully) by the actinolite rocks next described.

Hand-specimens of the uralitised dolerites are usually greyish-green and of medium grain. Small hornblende prisms seem to make up more than half the rock. Small yellowish or greenish-white felspars are scattered through the hornblende mass. With the microscope, quartz is usually found as an original constituent, but it is very rare or absent in 52d, 53d, 54d, $\left[\frac{1}{334}\right]$. The relative amounts of uralite and felspar vary, uralite being predominant in 52d, while $\left[\frac{1}{303}\right]$ has much more felspar than uralite.

These rocks very occasionally carry quartz veins which are apparently quite barren.

(b) *Actinolitic, zoisitic Rocks.*—The usual rock of this variety is a partially sheared zoisitic amphibolite or epidiorite formed by dynamic metamorphism from the dolerite last described, to which its field relation has been indicated. Actinolitic rocks are notably developed only at the "Old Battery" and Kyarra Groups at the north end of the Area.

This rock can be recognised in hand-specimens by the obvious needles of actinolite forming a felt through the rock. Usually the actinolitic rocks resist weathering, and their toughness and refusal to break in any particular direction distinguish them from all other rocks found outcropping.

Two varieties are recognised by microscopic work:—

(i.) Extremely fine-grained rocks made up of minute felspar laths with zoisite grains and hornblende needles. This variety is little if at all sheared. The only examples collected are $\left[\frac{1}{341}\right]$ and $\left[\frac{1}{302}\right]$, which are derived from rocks like $\left[\frac{1}{334}\right]$ (fine-grained dolerites).

(ii.) Intensely fibrous, contorted, sometimes platy, fibrous amphibolites. These do not show felspar laths and are derived from such rocks as 52d.

It is clear that, though these varieties and perhaps others can be distinguished, transition-forms are abundant and there is no reason to regard the two as more than varieties of the same rock.

The actinolitic, zoisitic rocks occasionally carry small quartz veins which appear to be barren.

(c) *Massive Amphibolites.*—In many places patches of massive rock too decomposed for profitable minute examination have been found and mapped under this title, for they seem more likely to be decomposed rocks allied to (a) above than weathered peridotitic rocks. They appear to be quite barren and call for no further notice.

(d) *Hornblende (Batavia) Schists.*—A belt of these rocks extends from the southern limit of the Area to some distance north of the Batavia workings.

Hand specimens are very dark coloured or black, and vary considerably in texture and obvious schistosity. Further descriptions are given in Chapters VI. and VII.

Economically these rocks are of slight importance so far as the Meekatharra Area is concerned, the only workings in them being those of the Batavia.

(e) *Sheared Amphibolites (Yaloginda Schists).*—The rocks thus designated form the bulk of the country round Yaloginda. Their common parentage with subdivisions (a) and (b) is undoubted, and they also show affinities to the more metamorphosed greenstone described below.

The few comparatively unweathered specimens obtainable are light-green and greatly sheared, but have not the distinct flecks of the Paddy's Flat sheared dolerites.

In weathered specimens, rocks of varieties (e), (f), and (g) are indistinguishable, and, owing to the almost complete absence of underground workings between the Sirdar Group and Paddy's Flat, no attempt has been made to place any boundary between the "Yaloginda" and "flecked" schists.

Economically these rocks are important as they form the country both of the small, sometimes rich, veins of Yaloginda and of "lode formations" in the Karangahaki Belt.

(f) *Sheared Chlorite-Felspar Rocks* (*Kyarra Schists*).—North and west of the belt of Meekatharra granite is the greenstone "island" of Abbott's and Garden Gully. The centre and west of the part dealt with in this report is a plain, devoid of outcrops, from which rise a few "island hills" of the more massive greenstones (varieties (a) and (b)). The eastern part is gently undulating country very thickly strewn with the debris of the quartz reefs which not infrequently outcrop, and also showing outcrops of schistose rocks, the structure of which is obscured by excessive weathering or by surface silicification. Close to the granite, indeed, about 1¼ miles S.W. and 1¾ N.E., respectively, of the 29-mile post on the Garden Gully road, fairly fresh rocks of subdivisions (d) or (e) outcrop, but it is thought that the bulk of the country north of the granite is made up of schists of the kind found in the Kyarra and Eclipse Groups.

The best specimens of these rocks obtainable have suffered much from weathering. In hand-specimens they are generally dull green, rather fine-grained and show strong schistosity. Microscopically, though there are considerable differences between specimens from almost the same spot, the rock is broadly a felspathic chloritic schist probably derived by shearing from doleritic rocks. This view as to their relationship is confirmed by the occurrence in the Kyarra Mine of an actinolite rock closely associated with these schists, and of rocks $\left[\frac{1}{230}\right]$ passing into them and yet closely similar to the slaty dolerite rock (g) of Paddy's Flat.

Highly decomposed Kyarra schists are abundantly netted with gypsum crystals in some of the "Old Battery" shafts.

Veins have been worked in different places in the Kyarra schists, notably those of the Kyarra G.M. The country built up of these rocks deserves more thorough prospecting.

(g) *Sheared Porphyritic Chloritic Dolerites* (*Flecked Schists*).—The bulk of the country near Meekatharra is composed of rocks of this subdivision, which form a complex with the peridotitic rocks (*see* Plates IV. and XIII.). The separation of these two types in the field is often difficult and the boundaries are by no means as definite as would appear from the maps.

It will suffice to say here that the flecked schists are sheared talc-chlorite rocks showing chloritic or talcose patches, which are probably rolled out ferro-magnesian crystals, embedded in a ground mass which generally shows some trace of its doleritic origin.

In hand-specimens two varieties are easily recognised and are separated in Plate XIII.:—

(i.) *Flecked Schists.*—These—of which $\left[\frac{1}{197}\right]$ from the Queen of the Hill G.M. is typical—are characterised by their sheared character and the many darker lenticular patches, in places half an inch

long, arranged parallel to the shear planes. So conspicuous are these patches that the rocks were regarded as sheared fragmentals until the theory was disproved by further microscopic work.

(ii.) *Chloritic Slates.*—Found in patches amongst the flecked, Kyarra, and Yaloginda schists, these are believed also to have considerable development in the Jasper Bar Country (*see* p. 85).

The unweathered rock is a soft dull grey-green (sometimes pistachio green), coarsely jointed slate with imperfect fissility. Occasionally patches like those of the flecked schists are recognisable. Microscopically this rock is like the flecked schists.

Economically the flecked schists, forming as they do, part of the country of the most important ore deposits of the Area, are noteworthy. The same ore-channel when traversing both peridotitic and doleritic rocks (flecked schists) is usually larger and more uniform in the latter than in the former.

(h) *Some Talc-Chlorite-Carbonate Rocks.*—These, recognised only in the Commodore G.M., much resemble rocks of peridotitic origin, but microscopic study tends to show that they belong to the doleritic group. Further discussion will be found in Chapters VI. and VII.

(i.) *Fuchsite-Quartz-Carbonate Rock.*—This rock occurs alongside the Paddy's Flat Porphyry, in its southern part, and in the Ingliston Extended G.M. It is also found in the Ingliston and Commodore G.Ms. and (identified only by its highly weathered products) is mapped as extending thence south to the Ingliston Extended. Fuchsite rock is also strongly developed in the Globe G.M. south of the Paddy's Flat Belt. Some idea of the irregular distribution of this rock in depth is gained from the geological plans of the mines mentioned above.

Hand specimens from below the zone of oxidation are characterised by their bright green colour. They vary in grain from medium-coarse to fine and are usually very abundantly seamed with quartz veins (Fig. 50). Carbonate crystals showing shining cleavage faces and occasional small crystals of pyrite and arsenopyrite are the only recognisable minerals.

This rock weathers to a brownish gritty mass in which the quartz veins stand in strong relief. Sometimes the iron oxide segregates into bands of limonite leaving the rock bleached, save for a slight greenish tinge due to the presence of fuchsite.

Microscopic work shows that the fuchsite rock is probably a derivative of the doleritic, not of the peridotitic series, so far as the Meekatharra Area is concerned. This view receives a little support and no decided opposition from the observations made underground by the writer.

The quartz veins which traverse the fuchsite rock frequently yield gold, examples being the West Lode, Main Spur and auxiliary veins in the Ingliston Extended G.M., and the lodes of the Gwalia Extended Group and of the Ingliston, Commodore and Globe G.Ms.

2. *Of Peridotitic Origin.*—In the preceding division reference has been made to the complicated relationship between peridotites and dolerites and to the difficulty of distinguishing their highly metamorphosed representatives.

The peridotitic rocks may be subdivided into:—

(a) Talc-Serpentines.

(b) Carbonate-Chlorite Rocks (sheared in part).

(a) *Talc-Serpentine.*—This rock occurs most typically in four widely separated localities—on hills about two miles south of Belele Homestead, about 17 miles west of the Area; east of the Old Battery Group; in the Pioneer Group; and at the north end of the Karangahaki Belt. It is also found in places in the Paddy's Flat Belt. In each case the serpentine is closely associated with members of the doleritic series already considered—unsheared in the second, sheared in the other localities. There is no evidence to show whether the serpentine is merely a basic segregation of the doleritic magma or a separate intrusion.

In hand-specimens these rocks are soft and almost black. Under the microscope their peridotitic origin is fairly clear (Chapter VII.).

The unsheared serpentines contain no gold deposits.

(b) *Carbonate-Chlorite Rocks—in part sheared.*—The close relation between the doleritic and peridotitic rocks and the field-distribution of the latter—the great bulk of which are included in this variety—have been sufficiently referred to above.

In the detailed description of Paddy's Flat Belt the carbonate rocks are rather artificially divided into "sheared" (*i.e.* the "black schists" of the Ingliston Extended G.M.) and "little sheared" (*e.g.*, the carbonate rock of the Consols Group). It is probable that all are derived by shearing from rocks of the serpentine type described above.

When weathered, the strongly sheared varieties ("black schists") retain their gross structure, whereas the less sheared, highly carbonated varieties decompose far more extensively and assume rather the appearance of decomposed fuchsite rock. It is thus possible that some of the country mapped as fuchsite-carbonate (doleritic) rock solely on the appearance of weathered specimens belongs to the subdivision now under discussion.

If carbonate is less abundant the rocks weather to a clayey aggregate of talc and chlorite scales which, in the Gwalia Extended

Group and elsewhere, has been frequently mistaken for the Ingliston Extended dolerite, of which, apart from microscopic differences, it does not possess the characteristic colour and spheroidal weathering.

Oval concretions of magnesite are not uncommon in highly weathered portions of the carbonate-chlorite rocks.

IV.—SEDIMENTARY ROCKS.

In this section the writer is indebted to Mr. A. Gibb Maitland for the use of his notes and mapping of the sediments near Meekatharra and at Mt. Yagahong, also for his section of the latter; and to Mr. H. W. B. Talbot for many notes and for the correlation of the rocks under discussion with those further north.

Broadly speaking, the archæan granite-greenstone complex disappears north of the Meekatharra District under a succession of ancient sedimentaries. However, extensive archæan inliers do occur to the north, and, on the other hand, a few sedimentary outliers have been found in, or just north of, the Meekatharra District. These appear to belong to two series:—

A.—Older.

These lie north of the District as defined (Chapter I., p. 23) eight miles east of the Ruby Well leases.

They consist of conglomerates (and, south of the Harder to Find, also slates) vertical or dipping northwards at 60° or more, and contain small auriferous quartz veins. They are regarded as the same series as the Mosquito Creek beds which are extensively developed in the Pilbara Goldfield, where they are unconformably overlain by sandstones and conglomerates of the Nullagine series.*

B.—Younger.

These rocks cover an area of only about eight square miles in the District. Their most striking development is at Mt. Yagahong (Figs. 1, 14, 26, 27), and they are also found at Table Top Hill (Figs. 15 and 28), again 15 miles further north, and again near the Ruby Well Leases.

At Mt. Yagahong the lowest member of the series is a granitic conglomerate, above which comes a succession of dark, dense, close-grained rocks varying somewhat in texture. Although their occurrence in bulk leaves no doubt of their sedimentary character, hand specimens might be mistaken for a fine-grained "greenstone." A specimen [5334] was described by Mr. C. G. Gibson † as a basic

* A. Gibb Maitland, G.S.W.A., Bulletin No. 40.

† G.S.W.A., Bulletin No.14, p. 44.

tuff. Mr. Farquharson has determined the rock to be in part an arkose and in part tufaceous. The tufaceous facies shows such a close petrological resemblance to the fragmental volcanics described

Fig. 26.

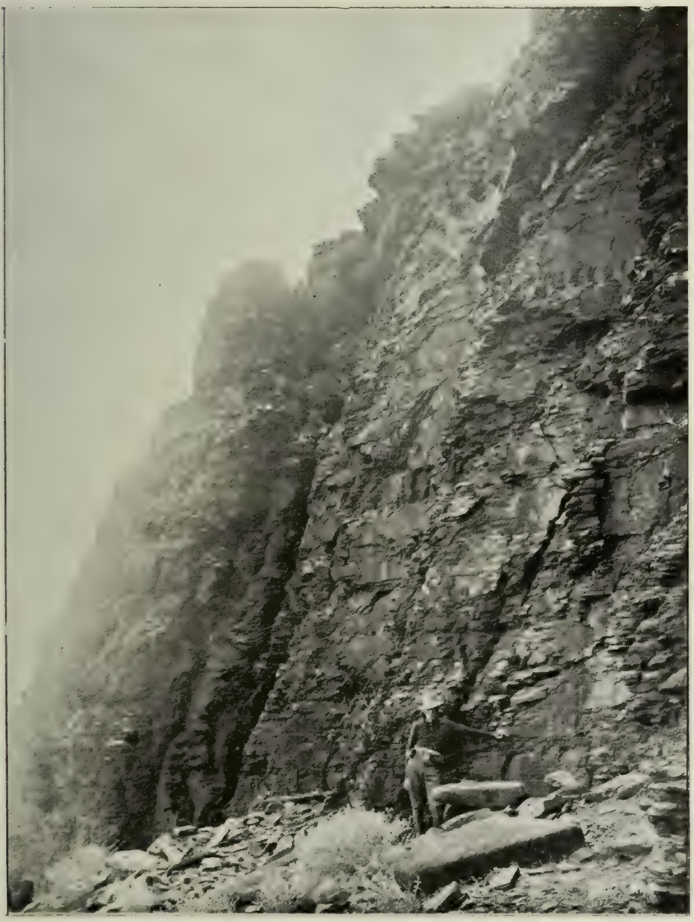
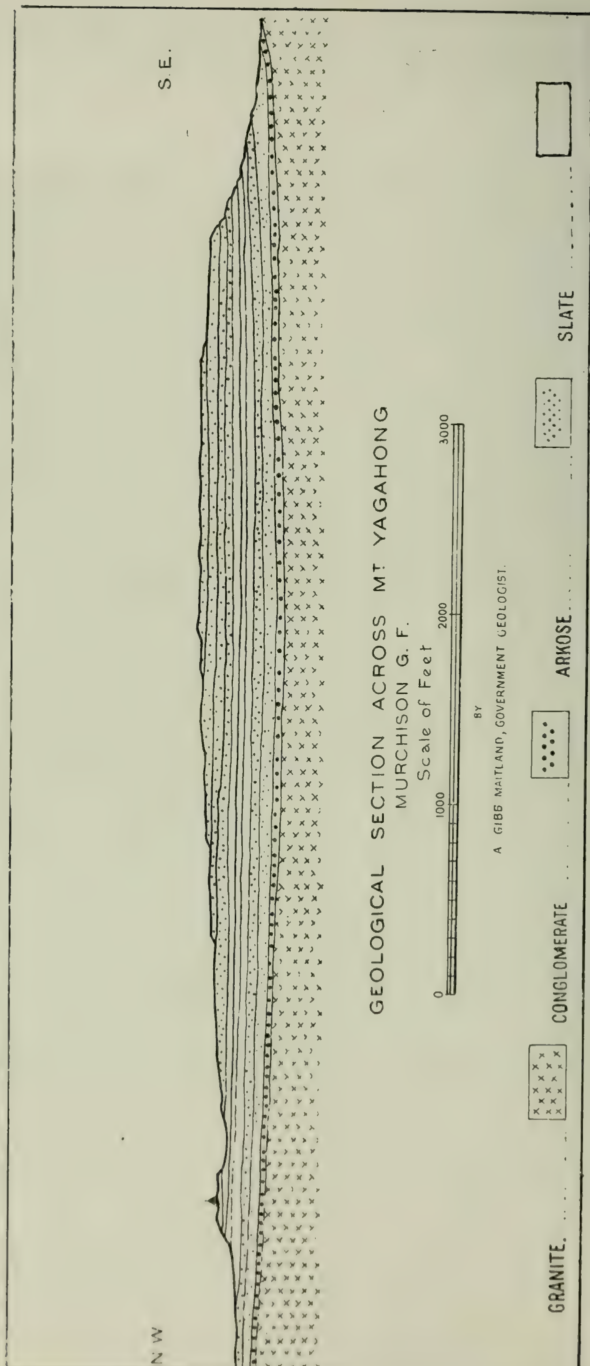


Photo.: E. de C. Clarke. Neg. 1297.

Horizontal Sedimentaries forming cliff on south side of Mt. Yagahong.

above (p. 65) that the latter may reasonably be regarded as further outliers of the same series.

Fig. 27.


N.W.
S.E.
GEOLOGICAL SECTION ACROSS MT. YAGAHONG
MURCHISON G. F.
Scale of Feet
0
1000
2000
3000
BY
A. GIBB MAITLAND, GOVERNMENT GEOLOGIST.
GRANITE.
CONGLOMERATE
ARKOSE
SLATE

The Table Top Hill rocks have not been microscopically examined. They are more shaly in character and are considerably more weathered than the Yagahong beds.

Fig. 28.

Photo. E. de C. Clarke. Neg. 1214.

Horizontal Sedimentaries, Table-Top Hill.

Mr. Talbot describes the occurrences further north as being of much the same character.

In all places the Younger Sediments are practically horizontal.

C.—Of Doubtful Age.

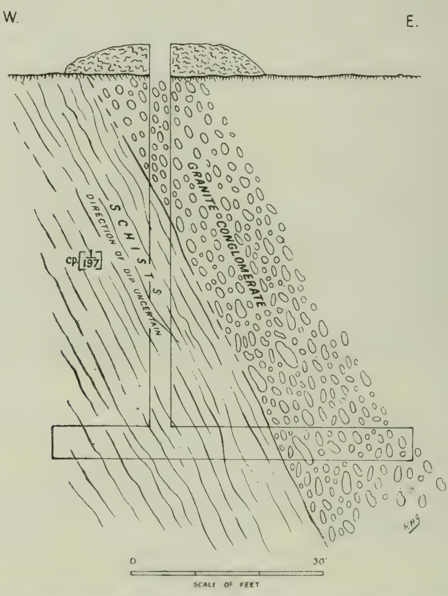
Close to the south-eastern edge of the Meekatharra granite in the Haveluck Group and its vicinity, fine-grained gritty sediments outcrop frequently, and are also found in Shaft 21 of the Haveluck Group (*see* Plate IX.) and in the Quarry Reserve, whence the rock has been taken for several buildings in Meekatharra. Their stratification is nowhere clearly seen, but in shaft 21 there is an apparent dip south at 58°. In shaft 20 an incoherent coarse conglomerate of water-worn "Southern Cross" Granite boulders lies unconformably on the flecked schists (Fig. 29). The direction of dip of the conglomerate and its relation to the gritty beds could not be ascertained.

The grits are yellow, or, in the case of the quarry rock, white, arkoses. In one place at the side of the Garden Gully Road they contain small quartz stringers.

Although these grits and conglomerates are mapped as Younger Sediments, their apparently inclined position and the presence of quartz stringers perhaps indicate more resemblance to the older sediments.

Excepting the building stone just mentioned, the sediments yield nothing of economic importance in the Area.

Fig. 29.



Relation between Schists and Granite Conglomerate.
Section through Shaft 20, Haveluck Group.

D.—Correlation.

The horizontal, younger sediments are thought to be outliers of the Nullagine Series which has its main development north of latitude 25° S. On the Canning Stock Route * the equivalents of the Nullagine beds are unconformably overlain by a series mainly of sandstones. These sandstones extend northwards to the Kimberley Goldfield, where they were mapped as Carboniferous by Mr. E. T. Hardman, † and where they unconformably overlie the rocks comprising the Albert Edward Range, which Hardman considered Devonian. These Devonian rocks in turn rest unconformably on the Hall's Creek auriferous beds.

* Talbot, G.S.W.A., Bulletin No. 39.
† Reports on the Geology of the Kimberley District. (Perth, by Authority, 1884 and 1885.)

The Younger Sediments of the Meekatharra District are therefore probably of Devonian age.

V.—SUPERFICIAL DEPOSITS.

The large area over which geological structures are masked by superficial deposits is approximately that shown as plains on Plate III., but, in addition, the greater part of the hilly greenstone tract is covered by such deposits as laterite, boulders, gravel, and soil, through which occasional greenstone outcrops project. The broken granite country is generally free from superficial deposits.

Superficial deposits are not mapped on Plate II., and on Plate IV. they are only indicated bordering on watercourses and where nothing can be inferred as to the underlying rocks. On the more detailed plans they are also ignored, unless in the total absence of outcrops or workings, surmise as to the character of the hidden rocks is quite unjustified.

The "alluvial" of the Meekatharra Area has yielded a considerable but unascertainable quantity of gold to dry-blowers. The most productive patches have been that near the north end of the Yalo-ginda Belt, those on the Black Jack Group, those near the Haveluck, Ralph's Patch and Bedford Groups, and that on the Kyarra Group.

The superficial deposits are of two kinds:—

A. Those formed by alteration of rock *in situ.*

B. Those formed of transported material.

There has been no attempt at systematic study of these "rocks." In a few cases (in which the rock had been mistaken in the field for a deep-seated one) microscopic examinations were made.

A.—Formed by Alteration of Rock *in Situ.*

Obviously no hard-and-fast line can be drawn between weathered, deep-seated rocks, and those so altered as to constitute a new rock. As acquaintance with local geology increases, the number of specimens regarded as hopelessly altered will diminish. A few cases of rocks greatly altered by weathering may be mentioned here:—

Two whitish, apparently massive rocks from the Explosives Reserve (5326), formerly suspected of being the southern continuation of the Beverley Dyke (*see* p. 60), yielded the following results under the microscope:—

[**11192**] A yellow-brown rather fine-grained, somewhat fractured rock. Under the microscope it is impossible to name the rock. It seems to be a silicified, completely weathered capping. Another specimen from the same locality has in section a somewhat sheared structure.

[11193] A peculiar cream-yellow porous quartzose rock with numerous small pale or blue-green patches. The porous, cellular, or minute vesicular character of the rock is quite pronounced, and

Fig. 30.

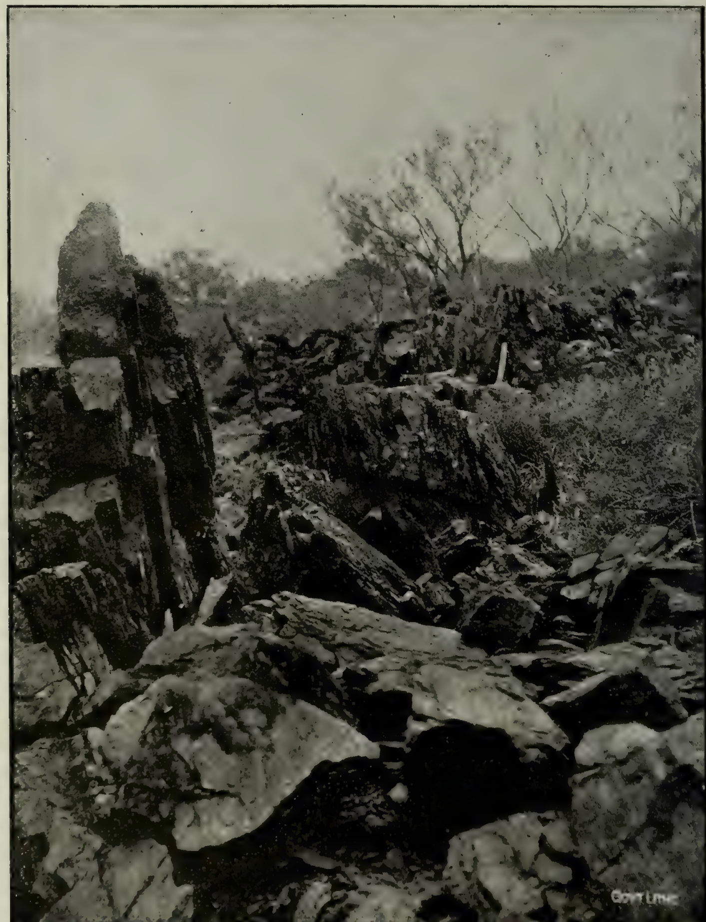


Photo.: E. de C. Clarke. Neg. 1412

Schists impregnated with Limonite and Silica on hill 50 chains west of 330½-M.P. on Railway Line.

gives it the appearance of a compact sintery quartz. The microscopic characters are very indefinite, and the rock resembles in some ways a compact sinter, in others a siliceous capping.

Another specimen collected by Mr. Farquharson in the neighbourhood of the Explosives Reserve proved to be a siliceous gritty and clayey capping of secondary origin, due to surface silicification.

Fig. 31.

Photo.: H. W. B. Talbot. Neg. 631.

"Dung Bitumen" in small caves in granite breakaways about 3¾ miles north of Meekatharra.

These descriptions are applicable to most of the whitish "rocks" found outcropping in the neighbourhood of Meekatharra, which are popularly known as "porphyries."

In the country supposedly underlain by Kyarra Schists (p. 69) non-ferruginous siliceous bars having a general northerly trend and showing traces of shearing are of fairly frequent occurrence. No microscopic examination of these bars was made, but they are regarded as due to surface silicification of portions of the Kyarra Schists.

West of the railway line between Meekatharra and Yaloginda a similar alteration of the schists, accompanied however by abundant deposit of limonite as well as of silica, is sometimes seen (Fig. 30).

South of the Meekatharra Granite there is a considerable development of jasper bars, which are absent from the northern portion of the Area. Discussion of these features will be found in the next section, but since their character at the surface is so unlike that underground they deserve passing mention.

Attention may also be called to the false "alluvial"—really sheared dolerite which is deeply weathered *in situ*—near the Mystery and Maranui leases (*see* later pp. 194, 197).

B.—Of Transported Material.

Under this head come the widespread deposits of earth, sand, gravel, and boulders already mentioned. Their thickness is probably inconsiderable even on the larger plains.

The larger fragments may be of quartz or of country rock, and, particularly in the latter case, often show some rounding—caused partly by wind-erosion, partly by insolation, partly by chemical action. The glazing of the greenstone pebbles is due, not to sand blast, which roughens, as shown by the etching of derelict bottles, but to deposit of a film of iron-oxide on the surface.

In caves, accumulations of dung bitumen are not uncommon. In Fig. 31 the black material to the left of the hammer is bitumen (mixed with sticks and fragments of kaolin) which has fallen from the larger mass in shadow. The sticks, Mr. Talbot informs the writer, almost always occur, and are probably dragged in by rock wallabies. Deposits of this character have been formed by the drying up of water which has passed through beds of bat and marsupial guano and extracted therefrom organic matter, salts of potash, etc.*

* Chapter VIII., p. 306.

VI.—FAULTS, SHEAR-PLANES, ETC.

A.—Faulting and Shearing.

Generally speaking, faulting and shearing have taken place in two directions:—

1. *Slightly east of north*—the main system.

This is probably the most important single geological feature in the District, since it has imposed a schistose structure on much of the country, and has with few exceptions determined the lines of gold-bearing deposits. To it also is due the formation of Jasper Bars. Any rocks which have not yielded in some measure to shearing are barren.

As shown in the preceding part of this chapter, the Meekatharra Granite and the Metamorphosed Igneous Rocks have been subjected to this shearing, but the Basaltic Dolerite, Volcanic Series, Sedimentary Rocks, and Superficial Deposits have escaped it.

The main period of shearing is thus older than Devonian times, but it is highly probable that this period was a very long one, beginning before the injection of the granite and continuing at least up to the time of its complete solidification.

2. *More or less at right angles to* 1.—An east-and-west fissuring appears to have operated over the southern greenstone "island," but evidence for its action in the country north and west of the Meekatharra Granite is inconclusive. The amount of displacement effected by this system of fissuring never exceeded 200 feet and was generally very much less.

A few cases of the apparent displacement of Jasper Bars by transverse faults have been mapped by Mr. Talbot.

A fault affecting the Meekatharra Granite has also been mapped on Plate IV. by Mr. A. Gibb Maitland near the old Rifle Range (10358). Here, along a zone about two chains wide, the granite is traversed by strongly marked east-and-west shear-planes which are in strong contrast to its normal foliation-planes well seen in the neighbourhood. Mr. Maitland has traced this zone westwards for 50 chains, and finds also that the edge of the granite is about two chains further east immediately north of this fault than it is to the south of it. A faulting later than the granite intrusion is thus indicated.

All other cross-faults, such as those of the Haveluck and Fenian, are discussed in Chapter VI. They appear to be but little later than the longitudinal shearing. Some carry auriferous veins, others do not—for example, the South Fault of the Commodore G.M. is barren, while in the next lease (Ingliston) is a system of auriferous veins with the same strike (Chap. VI., p. 139).

B.—Jasper Bars.

Jasper bars occur in the neighbourhood of Yaloginda, but with this exception, they lie to the east of the railway line, occupying a belt barely three miles wide and extending in a S.S.W. direction from Luke's Trig. to the southern limit of the Area. Two types may be distinguished:—

Fig. 32.

Photo.: E. de C. Clarke. Neg. 1406.

"Quartz Blow" on N93, looking north from the termination of the jasper bar country.

1. *Meekatharra type.*—These, extending from Luke's Trig. southwards, agree in general characters with those of Sandstone,* Mt. Magnet,† and other parts of the State. Their influence on

* G.S.W.A., Bull. No. 62, p. 23, etc.
† G.S.W.A., Bull. No. 59, p. 92, etc.

topography is mentioned in Chapter III. Their course, mapped by Mr. Talbot and shown on Plate IV., is N.N.E. and S.S.W., except just south and east of Meekatharra, where, with the exception of one bar which persists on the old course beyond Luke's Trig., they

Fig. 33.

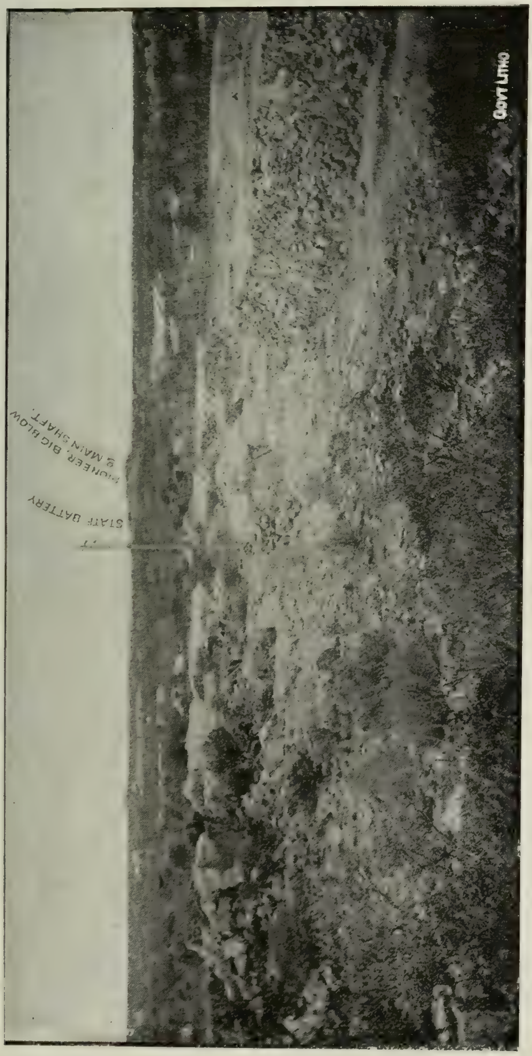


Photo.: E. de C. Clarke. Neg. 1396.

Pioneer Group. Old Workings on N93 in foreground.

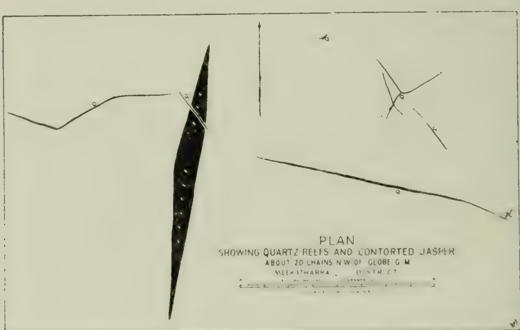
swing round to the E.N.E. and quickly terminate—probably lensing out. North of their ending the ground is level for half a mile, as far as the quartz blows of the Pioneer Group (Figs. 32, 33).

The Jasper Bar of the Queen of the Hill Mine is representative of the type under discussion. It can be traced almost continuously from the mine to the southern limit of the Area. The bluff shown in Fig. 7 is caused by the breaching of this bar by a small stream, and illustrates the surface-characters of these features. At nearly every outcrop it is a typical banded, contorted jasper, the bands being alternately rich in iron and in silica. They vary in thickness from paper-like sheets to bands an inch wide. The wider bands do not persist indefinitely, but suddenly give place to a series of the thinner ones. Occasionally, however, the jasper outcrops show little or no contortion. Again, almost within the limits of a hand specimen, intensely crumpled bands may alternate with others quite uncontorted, which themselves become intensely contorted a few inches further on.

The iron ore is mainly limonite, but, judging from the disturbance of the compass needle, magnetite is in places abundant.

The bar is in places crossed by small quartz veins of later date (Fig. 34—in which the black lens is an outcrop of contorted jasper).

Fig. 34.



Underground, above water-level, clay bands, iron-stained or bleached, alternate with the limonite- and silica-bands and make up half the bar. These softer bands are probably "hardened up" at the surface by additional deposit of limonite and silica. Owing to fault-disturbances the jasper in the Queen of the Hill Mine is more silicified and shows greater contortion than is usual.

Below water-level the jasper bar in the Queen of the Hill (which, being a locality of special mineralisation, is perhaps hardly typical of the ordinary bars at depth) retains its banded siliceous character—the soft layers of the weathered zone being here represented by layers rich in sulphides (chiefly pyrite).

Occasionally the Meekatharra jasper bars are brecciated at their outcrop, but this feature may be due merely to surface re-cementing of broken material.

2. *Yaloginda Type.*—At the surface the jasper bars of the Yaloginda Belt show no contortion and appear to contain very little silica. Wherever cut in workings they are found at a depth of 50ft. to be represented by greatly weathered sheared rocks showing no contortion. These only differ in their greater decomposition (with alternate leaching and concentration of iron-oxide) and shearing, from the surrounding sheared dolerites, etc.

3. *Origin.*—It is usually supposed that the jasper bars of the State have been formed along lines of excessive shearing.

When, however, the distribution of the Meekatharra jasper bars is examined it seems impossible to account on a theory of mere shearing for their absence from the northern greenstone "island" and for their sudden termination, with an east twist, south and east of Meekatharra. The latter feature might be explained as due to dislocation of the bars by a fault, or series of faults, of the east-and-west type common in the Area, were it not that the Luke's Trig. bar pursues the normal course, and that the northern dislocated portions of the others have not been found.

In the writer's opinion, the jasper bars of Meekatharra type were formed along zones of intense shearing where these zones traversed the fine-grained chloritic slates. Only in such rocks apparently could the peculiar structures characterising bars of this type be produced. This explanation of the distribution of the Meekatharra jasper bars is based solely on field work, no microscopic examination of jasper material having yet been undertaken. (*See* also Chap. VIII., pp. 292, 293.)

As shown above, the Yaloginda jasper bars are due to surface concentration of limonite along zones of exceptionally severe shearing.

VII.—SUMMARY OF GEOLOGICAL EVENTS.

From the material contained in this chapter the following summary of geological events may be made:—

The oldest rocks—already in position in archæan times—are a complex of doleritic and peridotitic character, regarding whose origin no opinion can be given.

The earliest event recorded is the beginning of a long period of earth-movement which first manifested itself in the production of north-east and south-west shear-planes in the bulk of the complex. Patches of dolerite and of peridotite, however, escaped the effects of this and the later movements. Accompanying the earlier

stages of shearing was the intrusion of the Meekatharra Granite * and the various acid dykes. In the former, foliation planes were produced by the continued shearing movements; the latter escaped owing to their position as narrow, compact bands, lying parallel to the shearing forces and enclosed by rocks which readily yielded to further movements. Continuance of the same tectonic disturbances resulted in the formation of Jasper Bars and was accompanied by the introduction of auriferous solutions—the last emanations from the Meekatharra granite magma.

In early palæozoic times, after a long period of denudation, the country was submerged and, at considerable intervals, two series of sediments were deposited. The occurrence of volcanic outbursts during the deposition of the younger beds—possibly in Devonian times—is indicated by the tufaceous character of some sedimentary beds at Mt. Yagahong. Probably the tuffs and flows near Meekatharra are of the same age.

After elevation and another long period of denudation the geological events of importance closed, possibly as late as in Tertiary times, with slight renewal of earth-movement along the old lines of the main shear-planes, accompanied by the intrusion of the Ingliston Extended dolerite and possibly also of the Barloweerie norite.

* Evidence is insufficient for us to determine whether the granite of Southern Cross type, near Yaloginda, is or is not merely a phase of the Meekatharra granite.

CHAPTER V.

LODES AND VEINS.

I.—INTRODUCTORY.

This chapter gives a generalised account of the veins and lodes of the Area. Details of individual occurrences will be found in Chapters VI. and VIII. to which reference must be made for confirmation of the general statements made here.

The term "vein" or "reef" will be used of any single body of quartz, large or small, whether auriferous or not. Small irregular veins are sometimes called "stringers."

A "lode" or "lode formation" is a group of closely associated veins together with the zone of rock (whether or not marked out from the "country" on each side by petrological or structural differences) to which the veins are confined. The lodes discussed in this chapter contain appreciable, but not always payable, quantities of gold.

Any of the sheared rocks described in the preceding chapter may carry veins or lodes. The more strongly the rocks are sheared the more likely they are, as a rule, to contain large and payable ore-bodies.

II.—ORE-BEARING FISSURES.

In the account of faulting in the last chapter, it was stated that two systems of fissures are recognised in the Area—one striking N.N.E. which determines not only the shear-planes of the schists but also the course of the most important lodes and veins, and a later east and west system, in places also carrying auriferous veins, which crosses and may displace the main fissure-system and its accompanying veins.

Except in the Ingliston Extended G.M., where the compound character of the West Lode and the possible strike-faults of the East Lode indicate renewed movement along the lode channels, there is no evidence of the re-opening of either system of fissuring.

The transverse system is probably but slightly later than the longitudinal and both followed shortly after the intrusion of the porphyry and Meekatharra granite.

III.—ORIGIN OF LODES AND VEINS.

Such occurrences as the "horses" of jasper bar material in the Queen of the Hill lode, and of schists in some of the Yaloginda veins (Fig. 71, No. 4), indicate that in many cases siliceous, and sometimes auriferous, solutions ascended along mere cracks formed by shearing, and that the quartz and accompanying minerals metasomatically replaced the country.

In the case of the quartz "blows," and such veins as the Kyarra ore-bodies and Savage's (G.M.L. No. 93) main vein, the only explanation for the great irregularity in size and shape appears to be L. C. Graton's*—that the siliceous solutions behaved like ordinary intrusions, making room for themselves by forcing apart the country in weak places. In support it may be noted that these irregular shaped quartz veins not infrequently contain small kaolinic patches —presumably decomposed felspars—and thus suggest relationship to more normal acid intrusives; possibly also the abundance of fluid inclusions noted in the few quartz specimens from such veins microscopically examined, favours the view that the veins solidified under great pressure.

It is probable that the siliceous solutions, whether or not intrusive, originated from the same magma as the Meekatharra granite and the porphyries, and were the last manifestation of the plutonic energy which caused those intrusions. This suggestion is supported by the obviously close relationship between several of the ore deposits and acid dykes.

IV.—METAMORPHISM BY LODES AND VEINS.

As noted in the last chapter, it is impossible to distinguish the alteration effected in the country by acid dykes from that by the veins closely associated with these dykes. This metamorphism is also obscured in the great majority of cases by weathering. The following are the most usual types of alteration:—

Bleaching, sericitization and albitization.—Bleaching and sericitization in the weathered zone are very noticable in the sheared "greenstones" near the net-work of veins forming the Gibraltar Lode, and near the veins of the Kyarra G.M.

* U.S.G.S. Bulletin No. 293, pp. 59-60.

In the weathered zone, the country adjoining the Pioneer, Paddy's Flat, Beverley, Haveluck, Ralph's Patch and Jasper Star porphyries is nearly always bleached for a distance varying from ten to a hundred feet. This feature is so common as to be a sure indication of the nearness of the porphyry. Below water level the bleaching is not seen, but the microscope shows that near the porphyry albitization has taken place. Bleaching results from the removal of iron compounds in the zone of weathering. Albitization has also taken place in the neighbourhood of the Romsey Dyke.

Formation of Carbonates.—This appears to be a very frequent contact effect of the Paddy's Flat Dyke. The commonest carbonates are calcite, siderite and mesitite.

Pyritisation.—The country for ten or twenty feet from the lode (and porphyry) in Paddy's Flat contains occasional crystals of pyrite.

V.—MINERALS OF LODES AND VEINS.*

The ore bodies of the Meekatharra Area contain but a small number of minerals. The *quartz veins* are usually destitute of minerals. Except tourmaline needles (in quartz from a shaft at the north end of the Sabbath Group, from another one and a-half miles S.E. of the Sabbath, from Jackson's Group, from the Gwalia Extended Group and in quartz pebbles near Rhein's P.A.), a few covellite crystals (vein near the "Two Sisters" quartz blow, near Yaloginda), and a single occurrence of azurite in Kyarra quartz, the only minerals (except gold) recognised were the very frequent kaolin and sericite, and the still commoner limonite-staining.

In the *lodes and veins* of the Paddy's Flat Belt pyrite, arsenopyrite and gold were the only metallic minerals recognised in hand specimens.

VI.—CHARACTERISTICS OF PAYABLE DEPOSITS.

A.—Field-occurrence.

Payable ore-deposits have sometimes been found in the Area outcropping, but usually they have been concealed by superficial deposits and their discovery has been due to the obtaining of alluvial gold, as in the Ingliston Consols Extended and Queen of the Hill mines.

B.—Distribution of Ore in the Lodes and Veins.

1. *Shoots.*—When stoping has been sufficiently extensive the payable ore of a vein or lode can sometimes be shown to be in "shoots" which "pitch" in a northerly direction. In the writer's

* An account of the minerals of the Meekatharra District is given in chapter VIII. by Mr. E. S. Simpson.

opinion this is by no means such a universal rule for the Area as is generally believed. Examination of the stope plans (Plates XIV. and XXIV.) indicates that beyond the fact that certain more or less vertical bands in the veins are more richly ore-bearing than others, the only cases, except that of the East Lode of the Ingliston Extended G.M., in which the ore is in north-pitching shoots, are explained by the influence of transverse, north-dipping veins.

2. *Surface Enrichment.*—Enrichment in the zone of oxidation (of which the Kyarra and Black Jack veins are good examples) has few exceptions as regards the auriferous veins. It must be remembered, however, that no quartz vein in the Area has been followed deeper than 300 feet, and that there is a possibility of reappearance of values at greater depths, such as took place in the Great Fingall Mine.*

In the case of the ore-deposits of Paddy's Flat Belt, the first workers, except perhaps in the Queen of the Hill lode, took only the richer quartz veins, whereas of late the ore has been bulked. It cannot, therefore, be proved that there was very striking enrichment in the zone of weathering whence the earlier gold returns were obtained.

3. *Influence of Country on Productiveness.*—The ore-bodies of the Paddy's Flat Belt are most productive where they lie in the "flecked schists" (sheared dolerites), are less productive when in the "black schists" (sheared peridotitic rocks), and are patchy in the fuchsite rock.

The veins of the Pioneer Group give their best yield in the sheared greenstones (both peridotitic and doleritic) close to the porphyry dyke, cease to carry values when followed further into the schists and are of low tenor in the porphyry.

The opposite is the case in the veins of the Beverley and Halcyon Lodes.

The Queen of the Hill Lodes are deposited along planes which fault the tip of a jasper bar, and carry payable ore where bordered on one or both sides by jasper, but cease to be payable where they enter the schists.

4. *Influence of Type of Fissure on Productiveness.*—Both systems previously described may contain auriferous veins, but groups (not single fissures) belonging to the main system (N.N.E. and S.S.W.) may persist for long distances and carry pay-ore at intervals; while the transverse veins, though sometimes rich, are short. The influence of the latter on shoots of ore in the main fissures which

* "The original or surface patch of enrichment upon which this mine was started proved to be of very limited extent, it's outcrop being 250 feet in length, whilst it only extended for a depth of 200 feet upon the lode plane gradually diminishing in length to about 100 feet at the bottom." Woodward, G.S.W.A. Bulletin No. 29, Part II., p. 18.

they intersect has been mentioned and is well seen in the Marmont and Fenian G.Ms., where the transverse fissures have in some cases diverted the gold-bearing solutions from the main channel.

VIII.—CLASSIFICATION AND COMPARISON.

A.—Veins.

1. Tabular or lenticular veins—generally steeply inclined or vertical and constant in strike—like those of the Yaloginda Belt and Sabbath Group.

2. Veins in Granite—Barren.

3. Probable ultra-acid phases of porphyry dykes—*e.g.*, veins of Jackson's and Pioneer Groups, and possibly the Kyarra ore bodies.

B.—Lodes.

1. Due to solutions emanating from the same source as the acid intrusives.

   (a) Deposited entirely (or almost entirely) outside the acid intrusives, *e.g.*, Paddy's Flat Lode.

   (b) Lode matter confined to dyke.

      (i.) Gold confined to quartz stringers, *e.g.*, Halcyon and Romsey Lodes.

      (ii.) Gold both in stringers and in felspathic part of the dyke, *e.g.*, Haveluck Lodes.

2. Siliceous impregnations of zones of sheared country—so far as known unconnected with acid intrusions, *e.g.*, Karangahaki and Gibraltar Lodes.

————

J. B. Tyrrell, at a meeting of the Royal Society of Canada in May, 1915, read a paper* on the "Pre-Cambrian Goldfields of Central Canada," presenting, amongst others, the following conclusions:—

> The veins are Pre-Huronian in age.
> They frequently occur both in basic and acidic rocks.
> They are constantly associated with albite porphyries which are apophyses from batholitic granitic intrusions.
> They do not occur in the body of the granite or gneiss.
> In the Algoman (Pre-Huronian) Period, in which most, if not all the gold-bearing veins of the Pre-Cambrian Rocks of Central Canada appear to have been formed, there was a Chrysogenetic Epoch during which gold rose from the deeper parts of the Earth and was deposited in such fissures as occurred at the time.

The geological age of the metamorphic rocks of Western Australia is unknown but it is interesting to note that, with this exception, the conclusions quoted above are applicable to the ore deposits of Meekatharra.

* Of which the writer has seen only the summary in "Economic Geology," Vol. X., p. 475.

CHAPTER VI.

MINES.

I.—INTRODUCTORY.

The order followed in this account of the mines of the Area is mainly geographical. When possible, however, without seriously interfering with this arrangement, ore-deposits similar in their geological features are grouped together.

The geological descriptions are, it is hoped, fairly complete, but extensive reference is necessary to Chapters IV., V., VII., and VIII.

The account of the history, gold-output, and state of development of the workings given in this chapter pretends to be complete only to the end of 1914.

II.—KYARRA GROUP AND NEIGHBOURHOOD.

Under this head will be discussed nearly all the workings on the northern greenstone "island."

A.—Kyarra Group (Pl. VI.).

1. *History, etc.*—This group is situated close to Garden Gully Creek and occupies a strip one mile long and half a mile wide. There is no record of the name of the first prospector. Probably Göczel,* in describing "Isak and Allower's" P.A. as one and a half miles *east* of the Old Battery Group (in which direction there are no signs of prospecting), referred to the first workings on the site of the Crown Mine, which is one and a half miles *north* of the Old Battery.

The Crown (G.M.L. 27N) was taken up by Oliver and party in January, 1895, and worked fairly continuously for 10 years. During this time, and though men frequently passed through to Abbott's and Peak Hill, the patch of "alluvial" and the underlying Kyarra ore-bodies lay untouched till about 1908, when they were discovered by Wilson, Cameron, and Edwards. The two latter acquired practically sole ownership of the Kyarra Lease (928N) (applied for in August, 1909). The Southern, or Main, Ore-body was first found. The discovery of the Northern Body in November, 1910, caused considerable excitement owing to the high values at first obtained. Four miles of country are said to have been pegged and many options taken up, including one of 14 days' duration over the Kyarra lease, £30,000 being mentioned as the probable price. The boom was short-lived, but Cameron and Edwards continued to work their lease very successfully, until, in 1912, it was acquired by the "Kyarra G.M. Co."

A number of other leases (four amalgamated with the Kyarra) were held in the neighbourhood, and a small amount of apparently fruitless work done on the various quartz veins.

The Kyarra G.M. was at the end of 1914 equipped with winding-engine and two Cornish boilers. A Cornish pump capable of dealing with 4,000 gallons per hour, 10-head mill, and cyanide plant are driven by two Dudbridge gas engines aggregating 185 h.p. Gas is supplied by two Commonwealth wood-producers totalling 235 h.p.

After amalgamation the pulp flows to the slimes dam, whence it is ultimately trucked to the cyanide plant, which consists of a filter vat of 18 leaves, five agitators (two overhead, two sunk, and one stock vat), three pumps, and zinc boxes.

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* Rep. Dep. Mines, 1894, Appendix, p. 41.

Table showing the Yield of the Crown Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
Previous to 1897	Crown, 27N	106·00	169·61
1897	do.	75·00	127·28
1898	do.	15·00	13·33
1899	do.	10·00	8·48
1900	do.	54·00	65·73
1901	Crown, 27N (by cyanidation) ..	..	140·68
	Total	**260·00**	**525·11**

Table showing the Yield of the Kyarra Ore-Bodies.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Silver therefrom.
		tons.	oz.	oz.
1909 ..	Kyarra, 928N	21·00	54·74	..
1910 ..	do.	408·00	893·95	..
1911 ..	do.	332·00	197·19	..
	Kanowna, 1036N ..	..	* 6·49	..
1912 ..	Kyarra G.Ms., N.L., amalgamated leases 928N, 1038N, 1037N, 1077N	304·00	335·71	..
1913 ..	do. do.	10,644·00	6,821·08	193·80
1914 ..	do. do.	11,875·00	9,582·61	704·80
	Total	**23,584·00**	**17,891·77**	**898·60**

* Dollied and specimens.

2. *Geology.*—(a) *Country.* (i) *Kyarra Schists.* With few exceptions the country is a strongly sheared rock, usually very decomposed, especially near the veins, where an abundant development of sericite is characteristic. Down to 200 feet it is usual, but not invariable, to find hanging-wall country red, footwall yellow or white. In the Crown, the average strike is N.E., dip S.W. at 60° or 70°. For the Kyarra, since the schists conform generally to the twists of the ore-bodies, there is no general direction of strike and dip. Where the ore-body takes a very sharp turn, the shear-planes of the footwall country seem to bisect the angle made by the two limbs of the ore-body. The variation in the character of the schists noted by the petrologist is observable also in hand specimens, and it was found that these changes were so frequent that no attempt could be made to map them. The country of the Northern Ore-body is somewhat less sheared than that of the Main. Further

details regarding these Kyarra schists are given elsewhere (pp. 69, 252). The balance of evidence favours our regarding them as exceedingly sheared igneous rocks of doleritic origin.

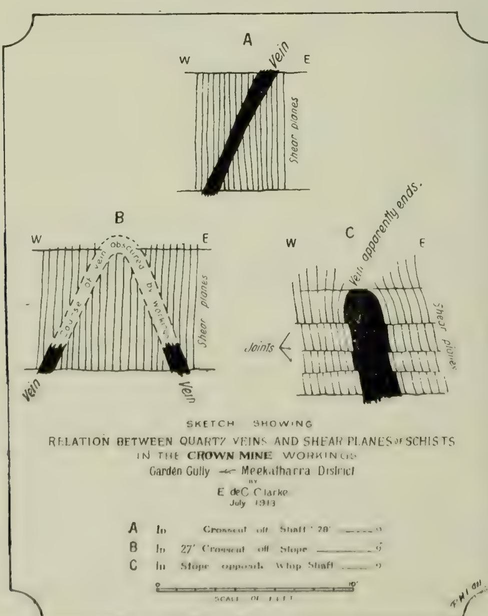
(ii.) *Actinolitic, zoisitic rock.* — This has been found outcropping in several places, where, however, its relation to the Kyarra schists cannot be seen. It is occasionally coarsely sheared, but rarely, if ever, carries quartz veins. Underground it has been encountered only in one part of the 100ft. level of the Kyarra G.M., where, on one side, it seems to pass gradually into the Kyarra schists, while on the other it is rather clearly marked off from them.

The actinolitic rock is presumably an unsheared, less altered portion of the rock from which, by great shearing, the Kyarra schists have been produced.

(b) *Ore-Bodies.*—The veins of the Kyarra Group are remarkable for their variability in size and direction.

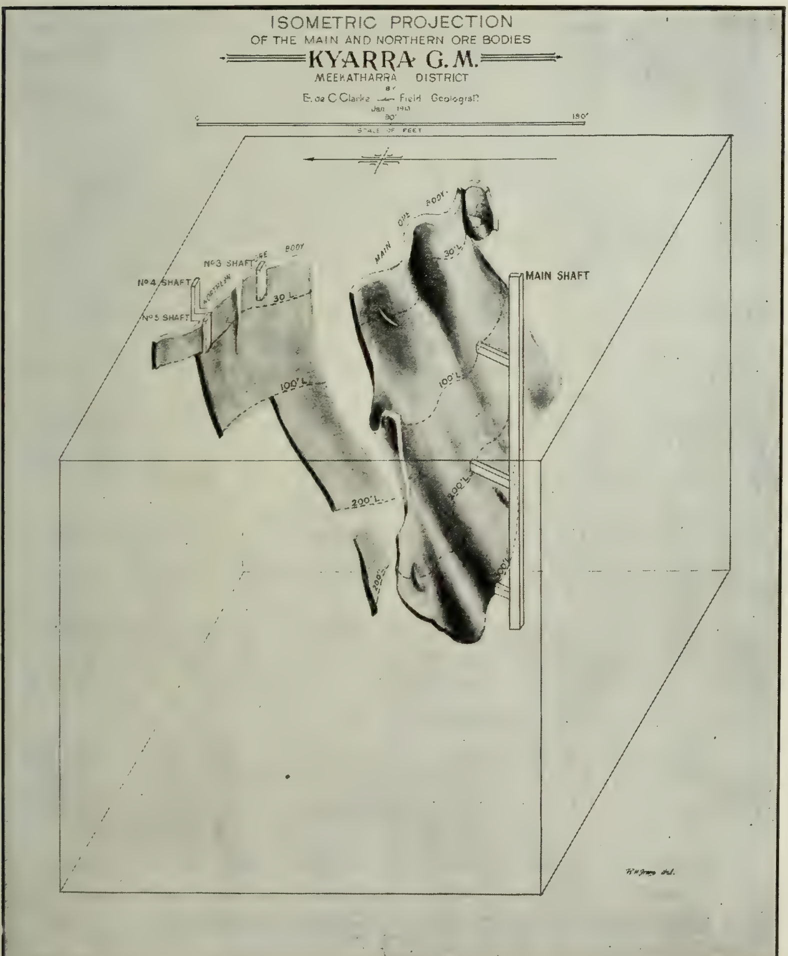
(i.) In the *Crown Mine* the main vein strikes parallel to the schists, but in the stoped parts dips *north-east* at 70°. Its south part is 2ft. thick and dips *south-west.* At the north end, it has split, the western (footwall) portion is a foot wide, and of bluish, compact quartz. The eastern (unworked) part is 4ft. wide, the central 2½ft. being "sandy," the rest compact blue quartz carrying specks of hematite.

Fig. 35.



The sections in Fig. 35, together with the vagaries of strike and dip noted, show clearly that the quartz veins are later than the shearing period, but that there was subsequent movement resulting in joints which affected both veins and country.

Fig. 36.



(ii.) In the *Kyarra Mine* three veins have been worked.

The Main Ore-Body strikes on the average a little south of east and dips south at greatly varying angles, the average being about

70°. It has been followed along the strike for more than 200 feet (in the 30ft., 100ft., and 200ft. levels). It has also been found at the 300ft. level and is said to yield assays ranging from a trace to 1,000s. per ton.

The plan and sections (Plate VI.) and projection * (Fig. 36) show the irregular course of this vein both vertically and horizontally. It is said to have an average width of nearly 9 feet, but is practically discontinuous in at least three places. The erratic character of the vein seems to be due to irregularity in the fissure into which it was injected, and not to subsequent faulting. The vein is, however, crossed by joint-planes filled with gouge, which are more numerous at sharp bends than elsewhere.

Between the 30ft. and 100ft. levels a large part, but never the whole, of the vein is of "sandy" quartz (*i.e.*, of a quartz which readily crumbles to sand). Unfortunately, owing to loss of specimens, no investigation of the origin of this sandy character has been made. In the 30ft. level the quartz is very dark brown from the abundance of iron oxide leached from the bleached country and recementing the sandy quartz. In the lower levels, the quartz is white and compact. Pyrite, sometimes in well-shaped crystals, is frequent, and one occurrence of azurite with chalcopyrite is reported from the vein. In places the quartz is finely laminated with sericite. It also frequently shows "eyes" of kaolinic character, and this fact, together with the presence of well developed rods of yellow tourmaline noted in the microscopic examination of the schists, favours the idea that the Kyarra veins are ultra-acid dykes (*see* also Chap. V., p. 88). No further evidence for or against this view could be obtained.

There is no indication of the existence of shoots of higher-grade quartz in the vein nor of the limitation of values to the foot- or hanging-wall portions of the vein. It is clear that down to 100 feet there was very extensive secondary enrichment.

The *Northern Ore-Body* strikes W.N.W. and dips S.W. at about 70°. It has been followed for about 130 feet in the 30ft. level—from which part the richest ore in the mine was got—and has been found but not explored at the 100ft. and 200ft. levels. It terminates abruptly at its south-eastern and tapers out at its north-western end in the 30ft. level. It resembles the Main Body in character of quartz and range of values and varies in width from 1ft. 6in. to 5ft.

The *Western Ore-Body* has been located in prospecting shafts over a distance of 250 feet and possibly at the end of the west cross-cut at the 100ft. level, but has yielded little or no payable

* The writer is indebted to Mr. F. R. Feldtmann, Field Geologist, for much help in preparing this figure.

quartz. It strikes E.N.E. and dips west at about 55°. Its quartz is similar to that of the other veins, but is not so heavily iron-stained. The vein nowhere exceeds two feet in width.

The potholes north-east of the main shaft have yielded values up to 22s., but no defined ore body has been located in them.

B.—Eclipse G.M.L. and Neighbourhood (Pl. V.)

The Eclipse (G.M.L. 1108N) was held for a little more than a year in 1911-12. The only recorded yield is 3.93oz. of fine gold from 16.25 tons of ore in 1912.

The country $\left[\frac{1}{231}\right]$ * is Kyarra schist similar to that described above.

Two veins striking N.W., dipping S.E. at 35° to 60°, and varying from mere films to 4 feet in thickness, have been worked slightly. The quartz as a rule is bluish in colour and much jointed. In the water-shaft it is very similar to quartz of the Main Ore-Body from the 30ft. level of the Kyarra G.M.

Nearly a mile N.E. of the Kyarra Mine there are three potholes and some costeens on two veins of iron-stained quartz 3ft. and 1ft. thick, striking north of east, and dipping in opposite directions. The country is Kyarra schist.

C.—Old Battery Group (Pl. VII.).

(1) *History, etc.*—This Group consists of two long-abandoned leases, "Garden Gully" (427 Murchison) and "Garden Gully North" (415 Murchison), near the 32 mile-post on the Garden Gully Road. Applied for in May, 1894, these are the two oldest leases in the Area. No work of note was done on 415, which was originally held by W. Puddifoot, W. J. Kelly, and others. W. Puddifoot and R. Oliver were the original holders of 427, which in August, 1894, assed into the hands of the "Garden Gully G.M. Co., No Liability," of 80,000 shares, and by the end of the year the mine was equipped (according to an advertisement of May, 1895) with "a 14 h.p. Cornish boiler, 8 h.p. vertical boiler, 10 h.p. horizontal engine, 10-head battery of 750lb. stamps," and accessories. Though little, if any, quartz was crushed from the Group itself, this plant treated nearly all the ore obtained in the Area until 1901. The Garden Gully G.M. Co. seems to have collapsed soon, for the lease was forfeited in July, 1896, and little or no mining has been done there since.

S. Göczel reported † in August, 1894, "about 700 tons of auriferous stone at grass." The writer has found no record of this or any other ore won on the Group having been crushed.

* Numbers are those of specimens described in Chapter VII.

† Rep. Dep. Mines, 1894, Appendix, p. 41.

The tailings, accumulated from public crushings and amounting to 2,000 tons, were cyanided in 1901.

(2) *Geology.* (a) *Country.* (i.) *Actinolitic rocks.*—The neighbourhood of this Group is the most favourable locality for the study of these rocks, which frequently outcrop. An account of them is given in describing the Kyarra Group and elsewhere (pp. 67, 238). It may be noted, however, that two varieties are here represented; one (*e.g.*, $[\frac{1}{300}]$ is like that described from the Kyarra; the other $[\frac{1}{302}]$ is much finer in grain, more obviously doleritic, and without the actinolite needles and felted structure of $[\frac{1}{300}]$.

(ii.) *Kyarra Schists.*—The main workings are all in soft yellow iron-stained (or bleached) schists, which could not be examined microscopically, but resemble weathered schists of the Kyarra type.

(iii.) *Massive Amphibolite* (?).—No. 3 shaft is in one of the patches of the highly decomposed massive rock which occur throughout the Area (*see* p. 68).

(b) *Veins.*—None of the workings except those off the main and No. 4 shafts have located quartz veins of any size. The gold which, it is said, can always be got by panning the superficial debris on lease 427, was probably derived from the secondarily enriched cap of the complicated system of veins shown in the inset to Plate VII. In their erratic course and other characters (except their barrenness) the Old Battery veins are like those of the Kyarra.

Each of three samples (Lab. Nos. 7120-7122) taken in the main workings (for position see inset, Plate VII.) showed only a trace of gold.

D.—Lydia G.M.L. (1342N).

(1) *History, etc.*—This lease lies on level ground about one and a half miles S.W. of the Kyarra G.M. No outcrops occur, and the vein was found by sinking near some gold-bearing "floaters." Cement is 6 to 12 feet thick and increases the difficulty of prospecting.

Either L. Holtzmann and party, who early in 1912 crushed three tons from shaft 1 (Pl. IV., sheet A) for 17¼oz., or else E. Millbank, first found gold here. P. O'Brien and party began work in November, 1914, and found shaft 1 (with drives north and south in values nowhere rising above 52s.) and shaft 2 (with a cross-cut to the vein) previously sunk. They drove south on the vein in shaft 2, immediately got fair values, and after driving 60 feet entered a patch of quartz of which .03 tons yielded 28.60oz. (9.42 dollied). Since the beginning of 1915, 65oz. have been dollied and the shaft is being sunk to 100ft. Forty-two tons taken out in development have yielded 74oz. 5dwt., and values in the shaft are said to have improved from 30dwt. at 34ft. to 6oz. over 20in. at 50ft.

A Worthington pump of 5,000 gallons per hour capacity and a 12 h.p. vertical boiler are installed. Water level is at 30ft.

Shafts 3 and 4 in search of the continuation of the Lydia vein are apparently unsuccessful.

(2) *Geology.*—(a) The *Country* is a talcose sericitic schist very decomposed, resembling that of the Kyarra. Its shear-planes are parallel to the vein.

(b) The *Vein* varies from 2ft. to 6in. of yellow-brown quartz, strikes nearly north and south, and is vertical or dips very steeply sometimes east, sometimes west. The quartz where richest is vughy and is coarsely crystalline. The gold, in crystalline plates, is all, or nearly all, in the vughs. At the 30ft. level the vein is completely cut across by a cavernous horizontal parting. Below this there is rubble for 2 feet, after which the solid quartz comes in again.

E.—Sabbath Group (Pl. VIII.).

(1) *History, etc.*—The Sabbath Group lies on level ground (as much as 20 feet of "cement" was noted in some of the shafts) three miles S.S.W. of the Kyarra G.M. It has been the scene of four outbreaks of activity, involving the pegging of much the same ground in leases of various shapes and names.

The first find was in June, 1908, either by J. Woodhouse, who when shooting, stumbled on a line of rich "floaters," or by C. Phillips and party. At least eight leases, including the Sabbath (797N), were immediately pegged by various prospectors, but none was held for more than two years. A slight renewal of interest led to the taking up for a short time of the "Once More" and "Once More South." In 1913, four leases (the "Kyarra View" and others) were held for a little time and, by the latest accounts, the locality was again being tried in 1915.

Table showing the Yield of the Sabbath Group.

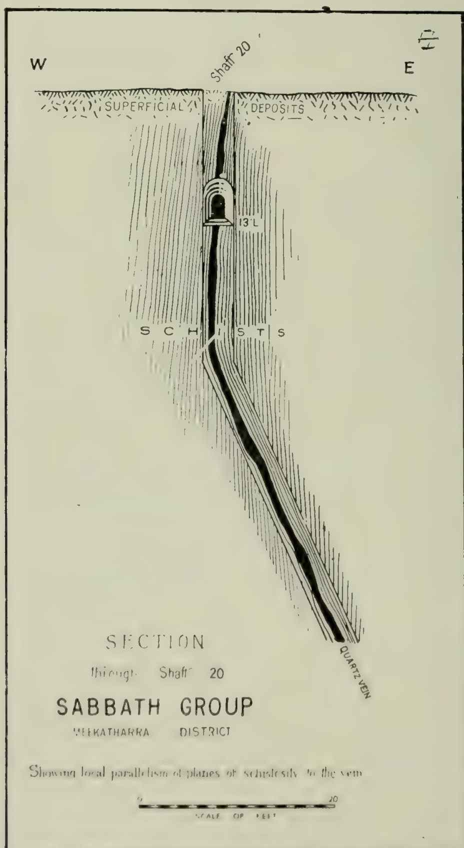
Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1909 ..	Sabbath, 797N	139·00	166·30
1910 ..	Once More, 1047N	79·00	90·39
1911 ..	do.	108·93	99·07
1913 ..	Booty, 1226N	12·10	6·55
	Kyarra View, 1221N	46·10	74·95
	Kyarra View North, 1222N	..	*2·43
1914 ..	Kyarra View, 1221N	30·00	5·95
	Total	**415·13**	**445·64**

* Dollied and specimens.

2. *Geology*—(a) *Country;* (i.) *Schists.*—These rocks, which are too decomposed for detailed examination, but resemble those of the Kyarra G.M., strike practically north and south and dip west at high angles. Near the veins, there are frequent thin leaves of quartz along the shear-planes.

(ii.) *Massive rock.* In shafts 18 and 17 is a highly decomposed spheroidally weathered massive rock, too decomposed for microscopic examination, but resembling the Ingliston Extended dolerite when weathered (*see* page 63). The rock is, however, mapped as the doubtful amphibolite remarked on in the Old Battery Group.

Fig. 37.



(b) *Veins.* These strike parallel to the shear-planes of the schists. At the north end they dip west very steeply or are vertical; those at the south end dip sometimes east, sometimes west, and in

the former case cut across the shear-planes of the schists which, however, have, immediately alongside the veins, been secondarily sheared parallel to them (Fig. 37).

The veins at the north end continued south on their strike would be 500 or 600 feet west of those at the south end. None of the Sabbath veins have been followed uninterruptedly for more than 150 feet, and it is unlikely that any persist for any great distance. They are seldom more than one foot in thickness (exceptions are those in shafts 12, 13 and 21). The quartz is generally rather glassy, occasionally blue, not much stained with iron-oxide, and frequently shows serpentinous and sericitic scales. The small stringers in shaft 3 show small tourmaline needles.

Gold is apparently found in short shoots and is rare in the wider veins. A sample from the bottom of shaft 21 where the vein is four feet wide yielded only a trace of gold (Laboratory No. 7112).

The longitudinal sections (Plate VIII.) show whence ore has been taken. A few tons were also obtained in shaft 2.

The prospectors are said to have found only one side of the vein worth removing, although the whole would have been payable with a battery on this spot.*

It has been thought† that the zones of quartz-impregnated schist referred to above as bordering on the veins carry payable amounts of gold, but the following assays of samples taken by the writer are discouraging:—

Laboratory No.	Locality and Remarks.	Result of Assay.
7113 ..	Shaft 23—Footwall of lode	Gold—Trace.
7114 ..	Shaft 12—West cross-cut, west section of lode	do.
7115 ..	Shaft 12—West cross-cut, across lode..	do.
7116 ..	Shaft 5—N.W. cross-cut, across lode..	Gold—1dwt. 7gr. per ton
7117 ..	Shaft 6—Cross-cut, across lode ..	Gold—9gr. per ton.

F.—Future of Mining in Kyarra Schists.

The country mapped in Plate IV., sheet A, as mainly Kyarra schists carries many veins, some of which have yielded small quantities of rich ore. Prospecting in the western part is greatly hampered by the covering of superficial debris. The many quartz veins outcropping in the eastern section deserve more methodical testing than they have yet had, and, from the character of their outcrops, will probably follow twisted courses like the Kyarra veins. Some

* Montgomery Rep. Min. Prog., Murchison and Peak Hill Goldfield, p. 57.
† Rep. Dept. Mines for 1908 p. 33.

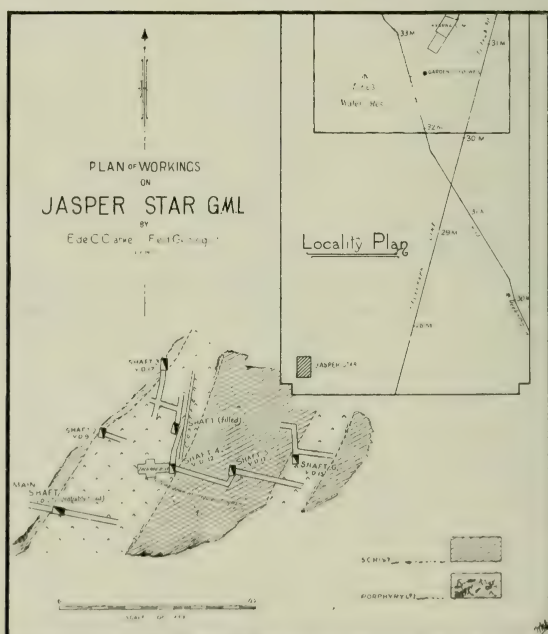
may reasonably be expected to contain gold, possibly in rich dabs, but probably no large payable bodies exist. The hard tough greenstones (actinolite rocks, etc.) are almost certainly quite barren.

III.—LODES OF THE HAVELUCK TYPE.

A.—Jasper Star Workings. (Fig. 38.)

(1.) *History, etc.*—Gold was discovered on this lease (about half-a-mile east of the Sabbath Group) in 1908, and the ground was held by G. Boyd and party for two years, since when the ground has been unoccupied. A four-acre "alluvial" patch, partly on the lease, attracted a good many men in August, 1908, but there appears to have been no warrant for the rush. The inextensive and shallow workings now open follow irregular quartz stringers. In 1908,

Fig. 38.



Scale: 120ft. = 1 inch.

however, Inspector Lander wrote*—"One reef [? shaft] has been sunk 53ft. to water-level. The reef was cut at the end of a 25ft. crosscut. It is 2ft. in width, but is not payable. Another shaft (probably No. 4 on Fig. 38), 60ft. north of the above has been

*Rep. Dept. Mines for 1908 p. 33.

sunk 15ft., and 20ft. of driving have been done. The reef is 18in. wide and very rich. Thirty pounds of stone gave a yield of 5oz. 18dwt. of gold." The vein of such promise in shaft 4 breaks up into stringers which die away in a few feet.

Table showing the Yield of the Jasper Star Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1908 ..	Jasper Star, 798N (alluvial)	..	26·36 *5·88
1909 ..	do.	·15	24·59 *22·00
	Total	**·15**	**78·83**

* Dollied and specimens.

2. *Geology.*—Below the "cement" the rocks are completely bleached and show no sign of original structure except an occasional trace of shearing. The supposed porphyry dykes netted with quartz stringers, which are mapped, are similar in character to those in the Haveluck Group (*see* page 108). The quartz stringers apparently contained the gold and it is on this account that the Jasper Star is included in lodes of the Haveluck type.

A shaft, nearly three miles south of the Jasper Star, near the old Nannine-Peak Hill track, sunk in schists of the Kyarra type on a vein which strikes N.E. and dips S.E. at 75° has apparently yielded a little ore, but is lost at a depth of about 20 feet.

B.—Haveluck Group (Plate IX.).

1. *History, etc.*—This group stands on high ground about one mile north of Meekatharra, near the granite. Gold was discovered here in 1894 by T. Creer,* who had to abandon prospecting the lode because men could not be induced to stay in such an out-of-the-way place. The Haveluck Lode was thus the first ore-body discovered close to Meekatharra.

B. J. O'Brien applied for the Haveluck Lease in October, 1898, but a crushing of 21 tons for 31oz. (or of 41oz. from 31 tons, according to another account), possibly taken from shaft 3† was not considered good enough, and the lease lay idle for a year, after which Mason and party began work and crushed 60½ tons from the 70ft. level for 190oz. From 1898 till June, 1914, the lease was constantly occupied by various parties, and was re-applied for in January, 1915.

* According to an account published in the *Murchison Times*, October 13, 1900.
† This return is not found in the Mines Dept. Statistics.

The leases norin and south of the Haveluck, generally known as the Lone Hand and King of the Hills, respectively, have been held under various names from time to time since 1899.

Table showing the Yield of the Haveluck Lodes.

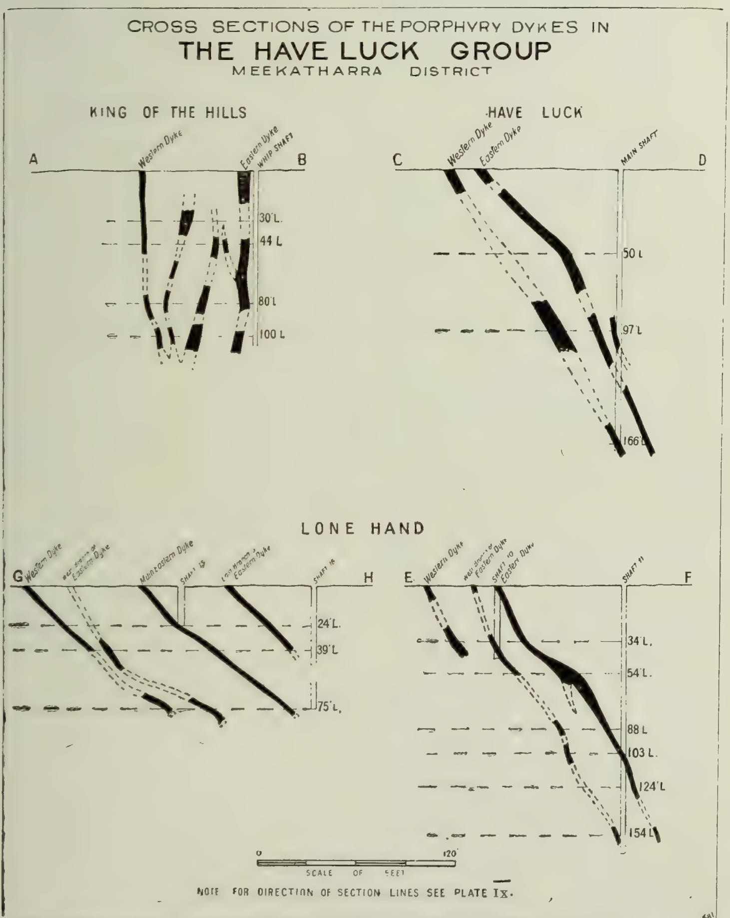
Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1899 ..	Haveluck, 236N	54·00	49·16
1900 ..	Do.	136·00	162·14
1901 ..	Do.	580·75	305·76
	Haveluck Extended, 257N	203·00	63·55
	Haveluck South, 279N	188·00	183·27
1902 ..	Haveluck, 236N	193·00	211·32
	Lone Hand (former 257N) 432N ..	300·50	139·84
	Haveluck South, 279N	394·00	236·05
1903 ..	Haveluck, 236N	711·50	428·89
	Lone Hand, 432N	104·00	21·33
	Haveluck South, 279N	563·25	173·08
1904 ..	Haveluck, 236N	158·00	126·70
	Haveluck North No. 1 (former 486N)	133·75	37·94
	Haveluck South, 279N	152·00	40·68
	Haveluck Consols (former 553N) ..	64·00	29·07
1905 ..	Haveluck, 236N	240·50	352·09
	Haveluck Proprietary, 592N (former 486N)	1,072·00	302·25
	Haveluck Consols, 553N	131·00	41·53
1906 ..	Haveluck Proprietary, 592N ..	400·00	90·55
	Haveluck South, 677N (former 553N)	36·00	15·87
1907 ..	Haveluck, 236N	466·50	218·87
	Haveluck Proprietary, 592N ..	1,168·50	263·20
	Haveluck South, 677N	19·50	11·87
1908 ..	Haveluck, 236N	234·00	38·58
1909 ..	Haveluck, 236N	32·00	48·62
	Lone Hand, 852N (former 592N) ..	53·10	46·96
1910 ..	Haveluck, 236N	444·00	123·10
	Lone Hand, 852N	149·00	306·56
1911 ..	Haveluck, 236N	484·97	298·59
	Lone Hand, 852N	103·75	94·11
	Do.	..	*·50
	King of the Hills, 1115N (former 677N)	25·00	77·46
1912 ..	Haveluck, 236N	448·67	333·72
	King of the Hills, 1115N	541·99	133·57
1913 ..	Haveluck, 236N	37·00	11·38
	Victory 1233N (former 852N) ..	63·00	15·40
	King of the Hills, 1115N	253·00	45·28
1914 ..	Haveluck, 236N	93·10	15·53
	Victory, 1233N	449·10	66·87
	Total	**10,881·43**	**5,161·24**

* Dollied and specimens.

It may be noted that the output of the individual leases is:—

Name and Number of Lease.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	oz.	oz.
Lone Hand	4,199·70	1,449·06	·34
Haveluck	4,313·99	2,724·45	·63
King of the Hills	2,367·74	1,087·73	·46

Fig. 39.



2. *Geology*—(a) *Country.*—Down to the lowest levels (160ft.) the rocks are so excessively decomposed that microscopic examina-

tion is unprofitable. They are sheared, the shear-planes running about 15° E. of N. and dipping steeply east. They are usually greatly bleached; the least altered specimens are indistinguishable from the "flecked schists" of Paddy's Flat.

(b) *Lodes.*—The lode material (Fig. 24) is a kaolinised unsheared rock carrying many quartz stringers which vary in thickness from mere threads to veins 1ft. or even 3ft. in thickness, and are confined to the unsheared rock. The latter is considered to be an acid intrusive, but is too decomposed for microscopic examination. The lodes are generally said to be three in number, but examination of the plan (Plate IX.), and sections (Fig. 39), shows that there are two which branch several times. Each branch may subdivide, as is well seen on the 97ft. level of the Haveluck G.M.L. and the 80ft. level of the King of the Hills. Enrichment is thought by those with practical experience of this group to take place at the forks.

It has been found impracticable to show all the branchings and irregularities of the dykes in the plan and sections. Their sudden changes in dip also make their projection to the surface difficult. In the plan they have been shown at about the 100ft. level and the calculated outcrop of their footwalls alone shown at the surface. Some of the connections are doubtful—thus the dyke in the "South Shaft" (King of the Hills) may be the eastern one, and it is probable that the east and west dykes join between the South Shaft and the main workings.

Two samples from the north end of the 50ft. level, Haveluck G.M.L., one containing only the quartzose, the other, as far as possible, only the kaolinic part of the dyke, were assayed with the following results:—

G.S.W.A. Laboratory No.	Character.	Result.
7107 ..	Quartz from dyke	Gold—7dwt. 9gr. per ton.
7108 ..	Kaolin from dyke	Gold—6dwt. 0gr. per ton.

From this it appears, as asserted by those who have worked on the Group, that gold occurs both in quartz and kaolin.

(c) *Cross-Faults.*—Several faults cut obliquely across the dykes, usually displacing them only a few inches. The cross-faults do not influence the tenor of the ore, and do not, as a rule, carry quartz or gold. However, at the north end of the 90ft. level, a little work has been done on a line of cross-faulting, where stringers of blue quartz of varying size have formed along the fault and where there is much ironstain.

3. *Dry-blown Patch.*—At the south end there is a dry-blown patch of about 10 acres, apparently on gold from the southern continuation of the Haveluck lodes. Many shafts have been sunk in search of the parent body without success. The majority are in a

Fig. 40.

State Battery, Meekatharra.

Photo.: L. E. Shapcott.

massive rock (so highly decomposed [$\frac{1}{180}$] that all trace of the original microscopic structure has gone) which is mapped with the doubtful amphibolites (*see* page 68).

C.—Ralph's Patch Group (Fig. 41).

(i.) *History, etc.*—This group is about half a mile N.E. of the Haveluck. Ralph was led by the discovery of "alluvial" (said to have yielded 270ozs. of gold) on this group to find the rich leader for which Ralph's Patch was noted. The "Multum in Parvo" (610N) was held by Ralph Bros. from 1905 to 1910. Though the same ground was afterwards occupied by other parties, apparently nothing of value was obtained, but in 1910 C. F. Connelly crushed 60 tons from an old dump for an average of 6½ dwt. per ton.

A good deal of exploration work by shallow levels just under the "cement" (which is 3ft. to 6ft. thick) has apparently been fruitless. The main shaft, now filled to 34ft., is said to have gone to water-level (about 150ft.).

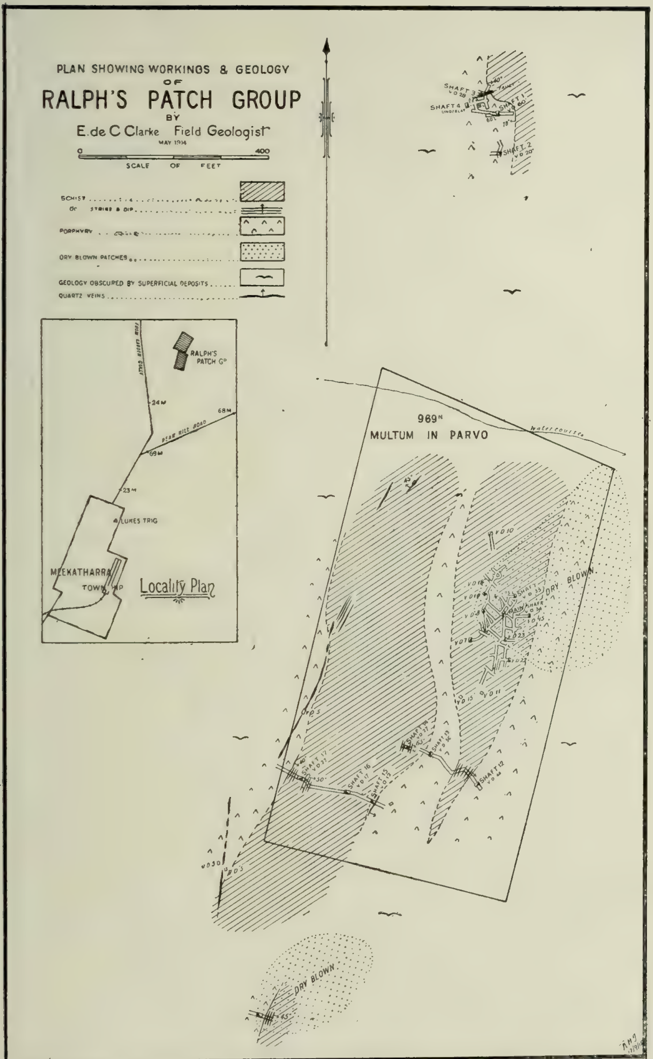
Table showing the Yield of the Ralph's Patch Group.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1906 ..	Multum in Parvo, 610N	7·00	82·33
1907 ..	Do. do.	34·11	1,486·16
1908 ..	Do. do.	·02	426·31
1909 ..	Do. do.	18·00	171·53
	Mt. Ralph, 855N (alluvial)	..	2·00
1910 ..	Multum in Parvo, 610N	3·00	8·71
	Multum in Parvo, 969N	266·00	37·64
	Total	**328·13**	**2,214·68**

2. *Geology.*—The highly decomposed country and the acidic dykes resemble those of the Haveluck Group; but the Ralph's Patch differ from the Haveluck dykes in their much greater size and comparative freedom from quartz veins. It is doubtful also whether the gold-occurrence at all resembles that of the Haveluck. Nothing is now left of the rich vein, but * in "a shaft about 20 feet deep the rich vein [was] about 2in. wide, running north and south and underlaying about 1 in 1 to the east." The rich vein is said to have been cut by an "ironstone indicator" dipping N.E., and though very rich at the intersection, to have been barren below it. It is reported that the gold occurred "netted together in an ash-like substance."

* Montgomery Rep., Dept. Mines for 1907, page 113.

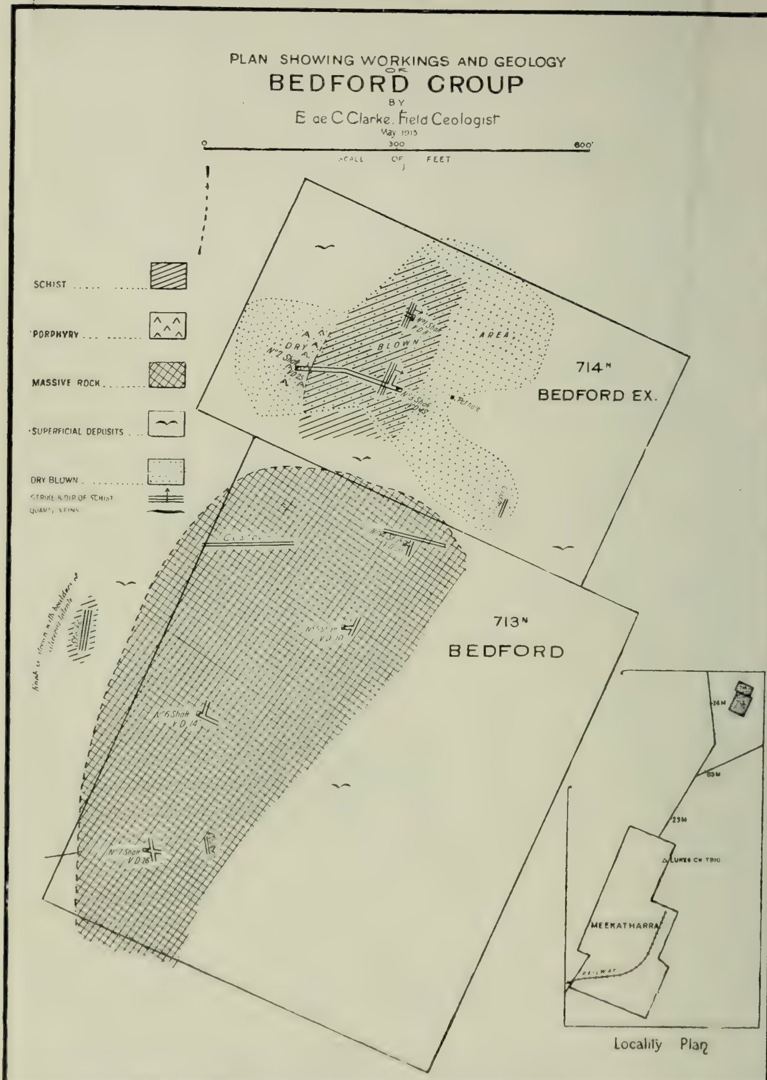
Fig. 41.



D.—Bedford Group (Fig. 42).

1. *History.*—The leases Georgina, Bedford, etc., were pegged early in 1907, but none were held for more than two years. The prospectors were no doubt looking for the source of the "alluvial," the dry-blowing for which covers a great part of the "Bedford Extended."

Fig. 42.



The longer edges of the plan run north and south.

2. *Geology.*—(i.) *Amphibolite* (?).—The shafts south of 2 and 3 are in a highly decomposed massive, perhaps of the type already described (p. 68). It occasionally, however, shows small seams of quartz.

(ii.) *Schists*.—These, seen in shafts 1, 2 and 3 strike N.N.E. and dip east at 45°. In general they resemble the schists of the Haveluck Group. Near the porphyry, however, they have a little of the green colouring shown by weathered rocks near the Paddy's Flat porphyry. It is quite possible that both the schists and the "amphibolite" are really of peridotitic, and not doleritic origin.

(iii.) *Porphyry*.—The dyke of acidic rock mapped has the same character as the porphyry of Ralph's Patch and is probably continuous with it.

E.—Future of Mining near Haveluck and Allied Groups.

There seems no reason to fear that the Haveluck dykes will show any marked impoverishment for a considerable depth. It is surprising that no attempt was made to deal with them in a larger way. Now that so much of the easily won shallow ore is gone, there is not the same inducement to equip a plant, unless, as seems quite likely, other auriferous porphyry dykes exist in the unexplored ground on either side.* Judging from their smallness the Haveluck dykes cannot extend far south of the King of the Hills. If there is such a southward extension it probably lies east of the prospecting shafts sunk in search of it.

The neighbourhood of the western porphyry dyke on the Ralph's Patch Group, with its two fairly persistent veins, deserves further prospecting, as does also the west side of the dyke in the Bedford Group.

Near the Jasper Star, also, other auriferous dykes probably exist. Here, as in other groups of this type, the only method likely to lead to the discovery of other ore-bodies is the search for auriferous "floaters" (they need not be rich) and patches, however small, of "alluvial."

IV.—OTHER SMALL GROUPS NORTH OF PADDY'S FLAT.

A.—68-Mile Workings.

A little work has been done a quarter of a mile west of the 68-mile post on the Peak Hill road on several very irregular quartz veins (Fig. 43). The highly weathered schists are here seen in contact with a kaolinised, quartz-seamed rock, thought to be a marginal phase of the Meekatharra granite (cp. page 54, Chap. IV.). The schists have been repeatedly faulted and injected with irregular quartz veins, the earlier of which have been faulted by the later.

A few tons of ore have been removed from the workings, but there is no record of crushings.

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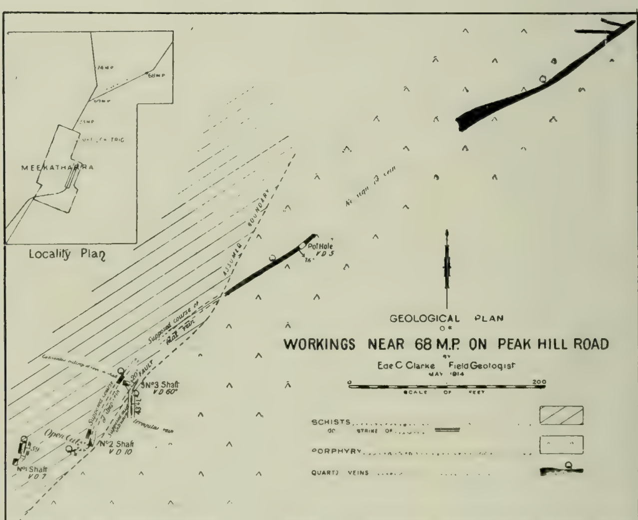
* For further discussion, see Montgomery, Rep., Dept. Mines for 1907, p. 113.

B.—65-Mile Workings.

Ten chains E.S.E. of the 65-mile post on the Peak Hill road, four 20ft. shafts with about 200ft. of driving and crosscutting are found (Fig. 44). The highly decomposed rocks are traversed by N.E. shear planes and have the character of the peridotitic rocks ("black schists") of Paddy's Flat.

A little ore has been taken out, but no records are available.

Fig. 43.



C.—Whitford's Group (Fig. 45).

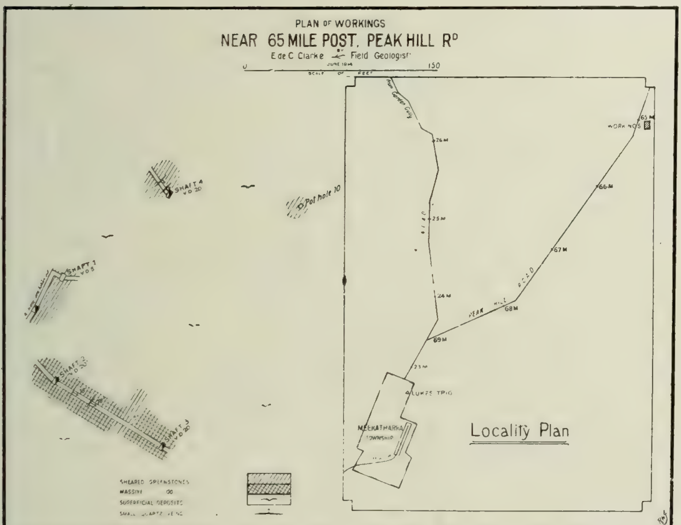
1. *History, etc.*—This group is about half-a-mile west of the 65-mile post on the Peak Hill road. In 1909 T. F. Whitford and another held the "Gold King" (878N, partly included in the later "Central" and "Macfarlane's Great View"), and "Gold King Consols" (882N). In 1912, the Great Fingall G.M. Co. had an option over part of this group which was thrown up after the few shafts, potholes and costeens had been sampled. In 1913-14, the main shaft was sunk, but the "lode," when intersected, was found to carry poor values, and these only on the footwall, and work ceased.

2. *Geology.*—The best specimens of the country are a bleached decomposed schist in which leaves of quartz parallel to the shearing are fairly common. At the surface, the schists are extensively silicified, and, in the case of the "Jasper Lode," charged with limonite said to have traces of gold. These schists show perhaps more simi-

larity to the Kyarra than to any other type, but are too decomposed for detailed work, and are mapped as flecked schists.

The "Main Lode" strikes N.E. and dips S.E. at 70°, *i.e.*, parallel to the schists, of which it is merely a belt very abundantly impregnated with quartz stringers and a good deal of limonite. It has been traced for about 700 feet, and varies in width from a few inches to 20 feet.

Fig. 44.



The shorter edges of the plan run north and south.

Particulars of the sampling are not available, but it is said that, though assay values up to 120s. per ton were got, there was no evidence of a continuous body of payable ore.

Two shafts about a quarter of a mile east of Whitford's have disclosed the boundary between granite and "greenstone," but are otherwise unimportant.

D.—Jackson's Group (Plate X.)

1. *History, etc.*—Jackson's Group is about a quarter of a mile east of the Peak Hill road between the 66 and 67-mile posts. The first find was in February, 1908, when the Nil Desperandum (774N) was pegged. The ground was successively held by four parties till the middle of 1915. The two other leases were held for short periods in 1910 and 1911.

Table showing the Yield of Jackson's Group.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1908 ..	Nil Desperandum, 774N	10·00	3·22
1911 ..	Wayback, 1072N (former 774N) ..	48·50	32·43
1913 ..	Do. do.	37·10	40·68
		..	*1·24
	Total	**95·60**	**77·57**

* Dollied and specimens.

2. *Geology.*—Highly decomposed, probably peridotitic, schists, somewhat coarse in grain, but finer at the north end, striking N.E. and dipping S.E. at angles of about 70°, form all the country seen in this group.

The workings are all on, or in search of, the same quartz vein which runs parallel to the strike and dip of the country and is never more than 2½ feet thick. The quartz seen by the writer was white and rather glassy with occasional limonite seams. Quartz said to come from the flooded 115ft. level, from which crushings averaging 1oz. to the ton* are reported, differs in showing the fine "capillaries" of clear quartz noted in Paddy's Flat (page 159). Near shaft 5 the vein is clearly divided into hanging- and footwall sections which, in places, separate to enclose small "horses."

In the flooded workings the vein is said to be crossed, about 80ft. down, by a vein dipping in the same direction at a flatter angle which "impoverished" the main vein for one foot above and eight feet below the crossing. However, a fragment said to come from the flatter vein (which is heavily charged with needles of black tourmaline) shows coarse "colours" of gold.

Two shafts a quarter of a mile north of Jackson's serve to define the boundary of the granite. Judging by the tourmaline-bearing quartz described above, an acid rock must intrude the schists nearer the workings of Jackson's Group.

V.—GROUPS WEST AND SOUTH OF MEEKATHARRA.

A.—Beverley G.M.L. (Plate XI.).

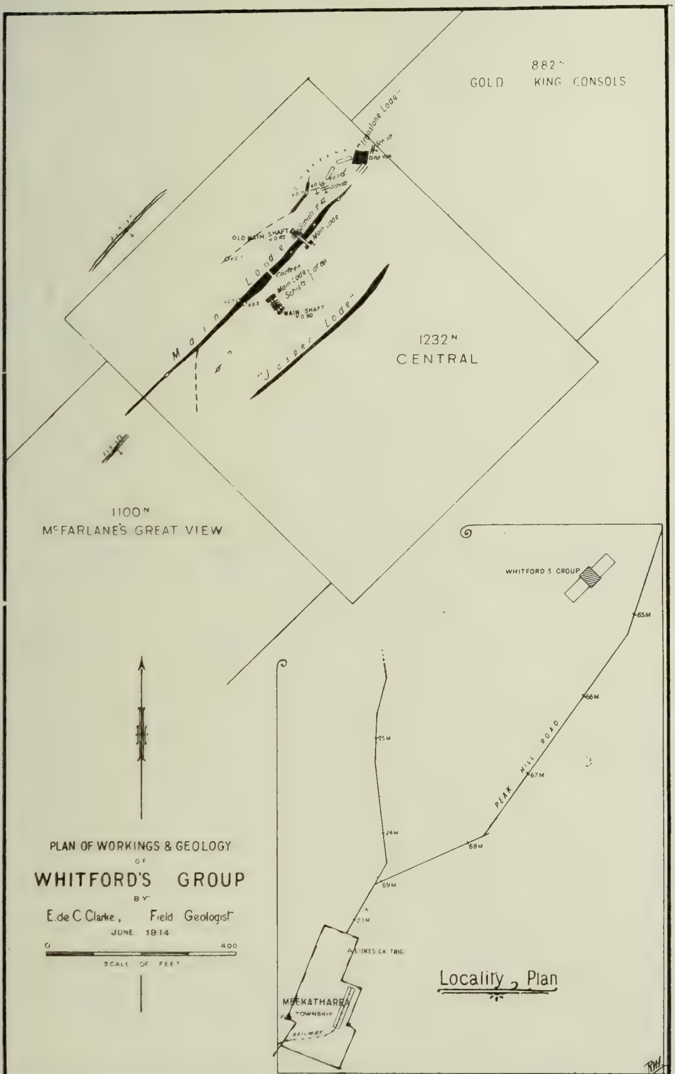
1. *History, etc.*—This lease occupies ground first taken up as "The Magpie" (471N), by C. Wright and E. Geary in June, 1903. The ground has since been pegged in various ways, but has never been held long.

* "All the ore taken from this property has crushed 26 dwts. per ton." Lander, Rep. Dept. Mines for 1911, p. 35.

Mr. W. C. Smith supplies the following account of the chief operations:—

Shaft 7* was the first sunk after the finding of small patches of "alluvial," but no crushings were taken from it. Shaft 13 was

Fig. 45.



* Numbers are those on Plate XI.

the next and from it 29½ tons taken as a sample gave only 4 oz. 2 dwt. by amalgamation. The property was then abandoned. Another party sank shaft 9 on a cross vein and crushed 100 tons for 99 oz. 6 dwt. by amalgamation. This vein was lost and after sinking to 150 feet, the lease was again abandoned. A third party sank shaft 11, which yielded 9 oz. 14 dwt. 4 gr. by amalgamation from 15 tons. Later No. 1 was sunk and gave only 3 oz. 19 dwt. from 33 tons. Shaft No. 16 gave a 15-ton crushing which returned 3 oz. 8 dwt. 18 gr.

Table showing the Yield of the Beverley Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1904 ..	Beverley, (535N)	44·25	6·94
1906 ..	Do.	100·00	93·51
1907 ..	Beverley Leases (535N) and (648N)	41·50	6·76
	Total	**185·75**	**107·21**

2. *Geology.*—In shafts 4 and 5, highly decomposed and iron-stained schists are exposed. Otherwise all the workings are in a kaolinized acid dyke traversed, except in shafts 14 and 15, by many quartz stringers which, though erratic in course, generally run east and west. These stringers swell out, join together and die away quite irregularly (Fig. 46). The general course of the Beverley dyke is seen on Plate IV.

The gold is carried by the quartz stringers in the porphyry, particularly those which strike east and west, and also, it is said, in the kaolinic parts of the dyke. The shoots of gold in these east-and-west veins are said to pitch to the east. Values are apparently not found in the veins which occur in the schists.

The gold-occurrence on this lease, therefore, shows resemblances both to the Haveluck and to the Halcyon types, and the remarks regarding the future of mining in the Haveluck Group, more especially the inducements for treatment on the spot, apply also to the Beverley.

B.—Coronation G.M.L. and Neighbourhood (Plate XII.).

1. *History, etc.*—This lease, although adjoining the Beverley, differs from it geologically.

The southern of the two quartz blows, lying close to the Nannine road, was thought barren until 1907, when Holtzmann and Devine sank a shaft and took out a 5-ton crushing which yielded

7oz. per ton. At a depth of 20 feet a "leader with splendid prospects" was cut. Since then, though a number of parties have held the ground, only one attempt has been made to test the vein at any depth.

Fig. 46.

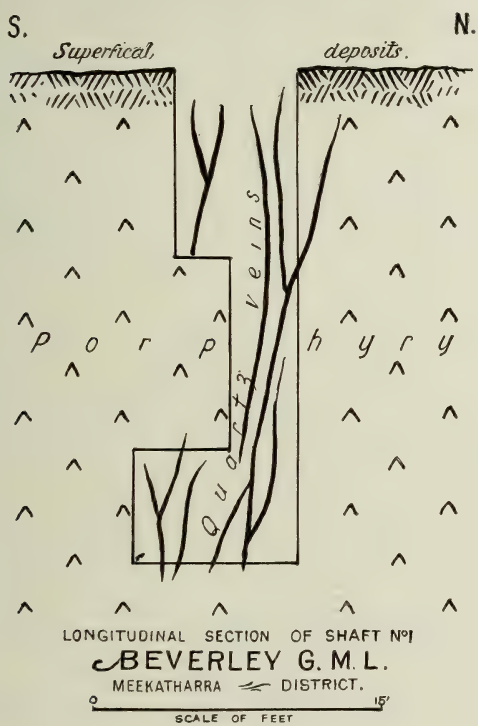


Table showing the Yield of the Coronation Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1907 ..	Lady Lorna, 748N	12·00	7·06
1910 ..	Swastika, 978N (former 748N) ..	81·00	29·40
1912 ..	Coronation, 1162N (part 978N) ..	27·05	18·66
1913 ..	Gilbannia, 1250N (former 1162N) ..	..	*28·83
	Do. do.	10·10	7·37
	Total	**130·15**	**91·32**

* Dollied and specimens.

2. *Geology.*—The country in these workings is a soft greenish schist, very similar to the "flecked schists" of Paddy's Flat, which strikes between 15° and 25° E. of N. and dips south-east at angles varying from 45° to 70°. This amount of variation, unusual in such a small area, is due perhaps to the nearness of the Beverley dyke.

Three shear-planes striking about east and west are shown on the plan. They do not seem to have affected the veins, and are therefore older.

The large quartz blow continues underground as several small veins, never more than one foot wide, running through the country roughly parallel to one another and to the strike of the schists, but dipping east at lower angles—never more than 45° and usually 20° to 30°. The quartz is vughy and white or bluish. The footwall-veins of this series have been the only payable ones. The continuation of these veins—apparently unpayable—is cut in the 72ft. cross-cut, making the average dip about 35°.

C.—Workings South and West of the Foregoing.

Most of these, being of interest only in that they help in mapping the geology of a part which shows few outcrops, call for no further notice here. Regarding the following, a few notes may be given:—

King George G.M.L.—On this forfeited lease, a quarter of a mile south of the Coronation, which was occupied for a short time in 1910, there are two shafts and about 40 feet of cross-cutting on stringers in the jasper bar country. Although this north end of the jasper bars is a part in which more prospecting should be done, the King George workings were resultless.

The Easter Eve Gift and Gift Extended Leases, a quarter of a mile S.E. of the King George, were pegged in April, 1905, have long been abandoned, and very little work has ever been done on them. They are in jasper bar country, but there are no particulars as to the mode of occurrence of the gold. The only record is that in 1906 the Easter Eve Gift yielded 2.01 oz. of specimen and dollied gold.

"Cameron's Shaft," near the 21-mile post of the Nannine Road, was sunk 25 feet, and about 100 feet of driving was done on small veins without a trace of gold, on account of the discovery of a boulder of "a sort of conglomerate" (probably quartz fragments cemented with limonite) rich in gold.

"Shaft F," about 10 chains east of the 20-mile post on the Nannine Road, is 40 feet down on a very irregular vein of bluish quartz. The country is a platy iron-stained schist, possibly of the Yaloginda type.

VI.—PIONEER GROUP AND NEIGHBOURHOOD.

A.—Pioneer Group (Plate XIII., Sheets 1 and 3).

1. *History, etc.*—The Pioneer Group, extending from the Pioneer lease in the north to N93 ("Savages") in the south and covering about 100 acres of quartz-strewn country (Fig. 33), lies close to the east boundary of Meekatharra Townsite. The group ends abruptly in the south at Savage's quartz blow (Fig. 32) and does not extend far beyond the hillock on which the Pioneer workings are situated.

In May, 1896, G.M.L. 90N ("Meekatharra," now the Pioneer) was applied for by J. Meehan, L. Soich, and T. Porter, G.M.L. 85N ("Little Sweetheart") by J. Regan, and 93N (N93) by L. H. Darlôt. These leases are, in the Report of the Department of Mines for 1895, p. 41, collectively referred to as the "Meekatharra Mine."

Darlôt, representing the "London and Perth Explorers, Ltd.," held a three months' option over 90N, and seems to have erected some machinery.* However, the return of 47oz. 7dwt. from 61 tons was considered unsatisfactory, and the machinery was sold. After being held as the "Centaur" for a short time, the Pioneer ground was taken up by D. Downie and the richer west vein discovered. The ground has been occupied ever since, and several options have been held over it. During 1905 or 1906 a main shaft (12ft. x 4ft.) was sunk, and Cornish lift and winding gear installed, but the machinery has been little if at all used.

"N93" was taken over by J. Savage in 1899 and held by him for 13 years, during which period the mine was twice under option and twice let to tributers. In 1899, the field had been practically abandoned, and for three weeks Savage was the only white man left at Meekatharra, but his first crushing (56 tons for 116oz.) attracted attention, and from that time Meekatharra has not looked back. †

The Sweetheart has been occupied at various times during the past 19 years.

A number of other leases have been pegged in the neighbourhood, the most productive being perhaps that originally occupied by J. Savage and party as the St. George (323N) in 1900. Work on the same ground, leased in various ways, was continued till 1912.

* *Meekatharra Miner*, August 14, 1909. † *Meekatharra Miner*, August 28, 1909.

Table showing the Yield of the Pioneer Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1895 ..	Meekatharra, 90N	61·00	39·44
1900 ..	The Centaur, 272N	99·00	75·72
1901 ..	Pioneer, 372N	283·00	216·30
1902 ..	Do.	888·75	850·03
1903 ..	Do.	1,124·50	1,724·45
1904 ..	Do.	967·00	746·33
1905 ..	Do.	79·50	33·20
1907 ..	Do.	80·00	30·15
1908 ..	Do.	103·50	172·42
1909 ..	Do.	1,007·00	1,061·52
1910 ..	Do.	907·00	580·94
1911 ..	Do.	463·94	445·10
1912 ..	Do.	205·39	67·82
1913 ..	Do.	137·50	59·79
1913 ..	Do.	..	*27·64
1914 ..	Do.	..	*3·13
1914 ..	Do.	270·10	74·82
	Total	**6,677·18**	**6,208·80**

* Dollied and specimens.

Table showing the Yield of the Sweetheart Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Silver therefrom.
		tons.	oz.	oz.
1901 ..	Little Sweetheart, 293N ..	22·50	12·20	..
1903 ..	Pioneer South, 426N (former 293N)	47·00	41·80	..
1904 ..	do. do.	111·00	82·83	..
1908 ..	Sweetheart, 789N (former 426N)	..	*78·52	3·00
1909 ..	Pioneer South, 866N (former 789N)	27·00	7·16	..
1910 ..	do. do.	16·50	16·19	..
	Total	**224·00**	**238·70**	**3·00**

* Dollied and specimens.

Table showing the Yield of the N93 Lease.

Year.	Name and Number of Lease.		Ore crushed.	Gold therefrom.
			tons.	oz.
1898 ..	Meekatharra South Block,	93N ..	53·00	135·60
1899 ..	N93	93N ..	72·00	110·40
1900 ..	Do.	do. ..	110·00	129·66
1901 ..	Do.	do. ..	753·00	482·19
1902 ..	Do.	do. ..	580·00	310·70
1903 ..	Do.	do. ..	593·50	161·01
1904 ..	Do.	do. ..	37·00	40·68
1905 ..	Do.	do. ..	469·50	163·00
1906 ..	Do.	do. ..	435·00	95·93
1907 ..	Do.	do. ..	811·50	272·41
1908 ..	Do.	do. ..	509·00	176·61
1908 ..	Do.	do. ..	..	*36·47
1909 ..	Do.	do. ..	1,071·00	478·53
1910 ..	Do.	do. ..	661·50	594·41
1911 ..	Do.	do. ..	308·36	220·98
1912 ..	Do.	do. ..	112·70	38·16
	Total		**6,577·06**	**3,446·74**

* Dollied and specimens.

Table showing the Yield of the St. George Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1901 ..	St. George, 323N	142·00	64·62
1902 ..	Do.	82·00	53·16
1903 ..	Do.	142·75	59·96
1904 ..	Do.	220·00	72·72
1905 ..	Do.	34·00	18·09
1907 ..	St. George, 710N (former 323N) ..	399·00	117·33
1908 ..	Recovery, 803N	214·00	48·66
1909 ..	Do.	30·00	3·27
1910 ..	Radium, 989N	48·00	5·87
1911 ..	Do.	69·95	45·83
1912 ..	Do.	40·57	76·00
	Total	**1,422·27**	**565·51**

Table showing the Yield of the Pioneer Block Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1901 ..	Pioneer Block, 373N	10·00	6·70
1901 ..	Phœnix No. 1, 402N	22·00	13·32
1902 ..	Do.	62·33	75·05
1903 ..	Do.	50·00	26·69
1904 ..	Do.	43·75	51·33
1908 ..	Occidental, 832N	19·50	12·23
1909 ..	Do.	300·00	60·89
1909 ..	Pioneer Continuation, 890N (former 402N)	35·00	17·40
1910 ..	Do. do. do.	75·50	16·53
1910 ..	Pioneer North Leases 743N, 832N, 890N	62·00	14·77
1911 ..	Do. do. do.	13·37	4·20
	Total	**693·45**	**299·11**

The total output from the Pioneer Group to the end of 1914 is thus 15,593.96 tons for 10,758.86 fine ounces.

2. *Geology.* (a) *Country.* (i) *"Greenstones."*—As a rule these rocks are too weathered to yield much information. Two types, one of peridotitic, the other of doleritic origin, are present.

Of the peridotitic rocks, which prevail in the most important workings, two varieties are distinguished. The more frequent is a strongly sheared talcose and chloritic rock similar to the "Black Schists" discussed in dealing with Paddy's Flat Belt. The other variety occurs at the north end of the Group: [$\frac{1}{364}$] and 509c from shaft 1, and the State Battery Well, are fibrous chloritic serpentines rather distinct from the Paddy's Flat rocks. The two varieties of peridotitic rocks from this Group probably differ only in the amount of shearing which they have undergone.

Two varieties of the doleritic rocks are also present—a fine chloritic slaty rock and a coarser "flecked schist." These are very similar to the "chloritic slates" and "flecked schists" described from the Queen of the Hill and found outcropping west of that mine.

It is hardly necessary to say that in this, as in most other cases, the boundaries mapped are supported by clear evidence only where they traverse mine workings.

(ii) *Granite-Porphyry.*—The extent of the Pioneer Dyke is shown on the plan, and needs no description. In most places the porphyry is kaolinised, but, from the deeper workings, fairly fresh specimens ([$\frac{1}{91}$ and $\frac{1}{102}$]) were obtained. Further descriptions of the occurrence and structure of this rock will be found in Chapters IV. (page 58) and VII. (pages 228-30).

(iii) *Relation between Porphyry and Greenstone.*—The sheared greenstones near the porphyry show, in the weathered zone, the same bleaching and green stain as do those bordering on the Paddy's Flat Dyke. In the east drive off shaft 34 there is a clear line of contact between the two rocks, the schist being silicified and there being a very irregular deposit of quartz along the boundary. The same type of contact is seen in shaft 35.

(b) *Veins.*—The porphyry is intrusive into the greenstone, but both rocks are traversed by veins which represent the last, most acid part of the porphyry magma, squeezed out after the bulk of the rock had solidified. The porphyry has been faulted along one of these veins in the Pioneer Continuation workings (Shafts 14 to 17).

Most likely all the quartz veins of the group are of this type, although the actual origin in the porphyry of some of the most important cannot be proved.

On the Pioneer are three main veins—the West, Middle, and East. Nearly all the gold has come from the West and Middle Veins. They probably join between shaft 2 and the open-cut, the junction causing the big "blow," part of which has now been removed, but which probably measured 50ft. x 200ft. at the surface and included two quartz lenses. This junction is also responsible for the shoot mined from the surface to the 170ft. level.

Underground, these two veins vary in thickness from a few inches to 9 or 10 feet (north end of West Vein at 107ft.). Both thin southwards, and the Middle Vein dies out, or is cut off by a strike fault at its north end. Both dip east, the West Vein steeply, but the Middle at low angles, becoming nearly flat at the bottom level (Fig 47), where it is joined by a 5ft. vein dipping east at 15° and carrying all the quartz below that level. The Middle Vein is, moreover, displaced by a strike fault at about the 100ft. level. Possibly a steeper branch of this vein has been missed at about 150ft.

The West Vein is composed of blue, the Middle Vein of "sugary" quartz.

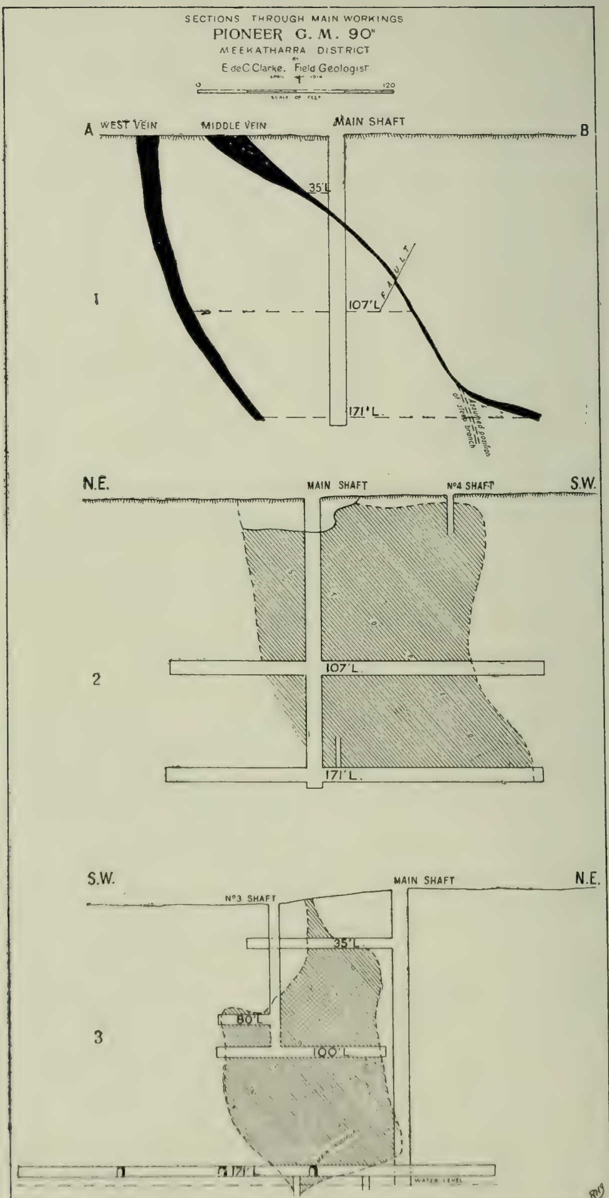
Since this survey was made, payable quartz has been found two chains east of the main workings, probably on a branch of the East Vein.

Besides the above, a number of small apparently valueless quartz bodies are found in the main workings.

On the "Sweetheart" the workings near shaft 13 follow veins dipping east at about 50° and similar to those of the Pioneer.

Shafts 14 to 17 are mainly concerned with a small vein of bluish quartz, which, cutting through porphyry and schist, carries high values in the schist for a short distance, being particularly rich

Fig. 47.



1. Cross section along line AB. (See plan.)
2. Longitudinal section of West Vein, showing stoping.
3. Longitudinal section of Middle Vein, showing stoping.

where small leaders enter it—nearly always on the hanging-wall side. There are numerous puggy partings in the vein, said to carry as high values as the quartz. At the 94ft. level the vein is two feet wide and is said to have yielded a crushing averaging 19dwt. to the ton.*

The workings in the south-east part of the "Sweetheart" are on a similar quartz vein, but, underlying it, is a pug seam in which are embedded large quartz crystals. Crystalline gold is said to have occurred in this deposit, which yielded, according to report, a small crushing averaging 26dwt. to the ton.

The productive workings of N93 may be separated into:—

(i.) Those off shafts 32 and 33, on two small veins striking through the porphyry in a N.N.W. direction; these are said to have yielded crushings averaging 25dwt. to the ton, down to the "68ft. level" (only about 40ft. below the surface, the measurement being taken from the higher ground at shaft 1), and are the only cases in this group of veins being to any extent productive in the porphyry.

(ii.) The main workings, which have produced the bulk of the gold, exploit parts of a vein in places approximately 50 feet wide, which would appear from its size, close relation to the porphyry, and the presence of interstitial kaolin to be a very acid phase of the porphyry. It has not been possible to obtain any account of the distribution of gold in this vein, but it would appear to have been patchy. The stope-section indicates a south-pitching shoot (Fig. 48).

Of this great vein, worked from the surface to 88 feet, no representative exists at the 150ft. level except an apparently valueless 3ft. seam of quartz found in places at the contact of schist and porphyry.

The workings on 93N, north of those just described, lie almost entirely in the porphyry, and seem to have been unproductive.

On the Pioneer No. 1 most of the workings are near the junction of three veins—two running generally parallel to, and one across, the prevailing strike of the greenstones. These veins dip at 40° to 60° to the east and south and are nowhere more than three feet thick. The quartz is like that of the West Vein of the Pioneer.

B.—Future of the Pioneer Group.

Considering the good yields obtained from small veins cutting through porphyry and greenstone, prospecting along the contact of the two rocks, largely ignored in this group, is certainly warranted. This is, however, unlikely to result in the finding of anything more than small rich veins. To obtain larger bodies of payable quartz the most obvious course is to explore further, both by drives and

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* *See* also Fig. 58.

winzes, the junction of the West and Middle Pioneer veins, and drive south from shaft 3 towards the main workings along the West Vein. Further horizontal prospecting, both by driving and cross-cutting in the main workings of N93, is also a reasonable proposition for those in search of large bodies of low-grade ore.

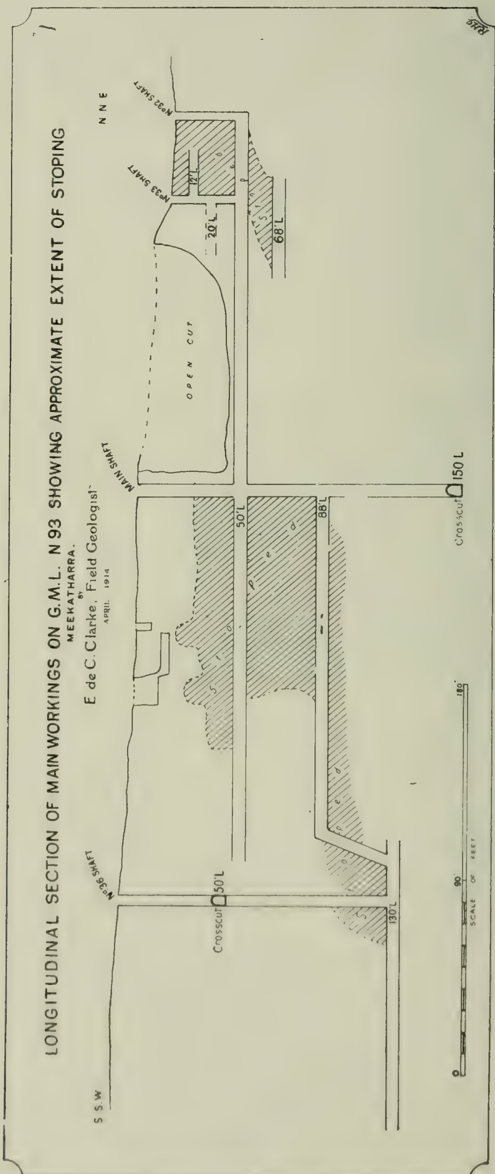


Fig. 48.

VII.—NORTH SECTION OF PADDY'S FLAT.

A.—New Orleans Group (Fig. 49).

1. *History, etc.*—This group, situated about three-quarters of a mile south of the 68-mile post on the Peak Hill Road, is geographically, if not geologically, the most northern working on the Paddy's Flat Belt.

J. Saddington, who first held the New Orleans (G.M.L. 624N) in 1905, and was led to prospect here by getting gold in floaters, took out a few small crushings. The lease was afterwards held by other parties, but neither it nor its neighbours yielded anything of importance.

Table showing the Yield of the New Orleans Group.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1906 ..	New Orleans, 624N	27·00	12·82
1907 ..	Do.	65·50	22·50
	Total	**92·50**	**35·32**

2. *Geology.*—Porphyry apparently occupies the western side of the lease. This rock is everywhere decomposed to a white clay, carrying many irregular quartz stringers.

East of the porphyry an altered peridotitic rock of the Paddy's Flat type is encountered. In places, however, it passes gradually into a rock [$\frac{1}{201}$] which appears to be fragmental. This, which is described in Chapter VII., may be called a pseudo-breccia, because by this term attention is drawn to the fragmental appearance of the rock—an appearance which can often be recognised in hand specimens.

The gold-bearing vein strikes N.N.W., dips S.W. at about 70°, is seldom more than nine inches thick and is of white glassy quartz, containing a good many flakes of fuchsite. This vein lies altogether in the "pseudo-breccia" and seems to die out as it approaches the porphyry.

Another, apparently unpayable, vein with a more westerly strike, has also been located.

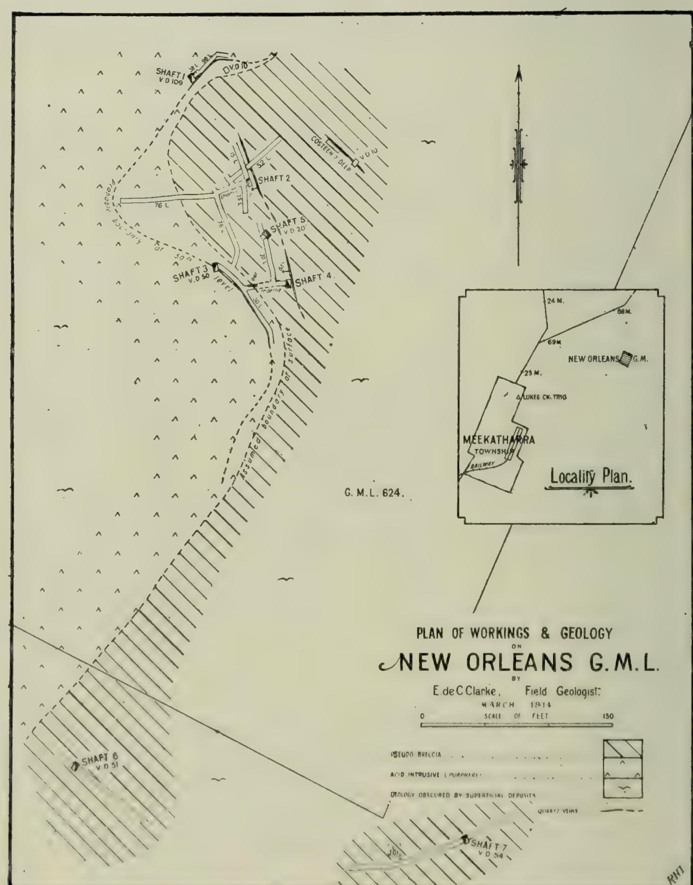
B.—Halcyon Group (Pl. XIII., Sheets 2 and 4).

1. *History, etc.*—The Halcyon Group, lying just north of the Commodore, should, owing to geological differences, be described separately from the latter.

The Halcyon Lease (313N) was pegged in January, 1900, by J. McNab & W. A. Vickers, passed through various hands, and is still being worked. Most of the gold from this lease came out of a large open-cut, which followed the lode down to 40 feet or more.

The adjoining ground to the north was held as the "Albion" by a Cue Syndicate in 1900, as the "Democrat" in 1902, as the "Despot" in 1904, and as the "Halcyon Extended" since 1905.

Fig. 49.



In 1910 and 1911 the "Democrat Options" Syndicate sank a three-compartment shaft, equipped with poppett legs and a winding-engine, to 260ft. and drove 480ft. south on the lode, which maintained its width, but was unpayable in the opinion of the syndicate.

An unsuccessful attempt was made in 1912 to form a company locally, and continue the work southwards, where it was thought the shoot of gold in the open-cut would be found.

The Halcyon and Halcyon Extended have latterly been worked separately by small parties.

Leases were formerly taken up north of the Halcyon Extended, but little work was done and the northern continuation of the Halcyon Lode has not been found.

The St. Francis (applied for in 1908 by J. Savage and J. F. Butler) and Commodore North (applied for in 1899 by D. McCallum and J. F. Butler), have been the scene of many attempts to find the continuation of the Commodore Lode. A large "formation" carrying gold, but not in payable quantity, has been located.

Table showing the Yield of the Halcyon Group.

Year	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1898 ..	Halcyon North, 318N	30·00	47·66
1899 ..	Do.	77·25	41·59
1900 ..	Halcyon, 313N	23·00	46·40
	Do.	..	*2·11
1901 ..	Do.	304·25	214·65
	Albion, 337N	25·00	8·77
1902 ..	Halcyon, 313N	181·50	198·76
	Democrat (former 337N), 425N ..	142·00	108·71
1903 ..	Halcyon, 313N	462·25	162·07
	Democrat, 425N	423·50	99·18
1904 ..	Halcyon, 313N	254·75	247·72
1905 ..	Do.	384·50	136·01
1906 ..	Do.	401·00	124·39
	Halcyon Extended (former 425N), 635N	78·00	22·70
1907 ..	Halcyon, 313N	742·00	137·73
	Halcyon Extended, 635N	153·00	320·16
1908 ..	Halcyon, 313N	73·50	21·39
	Halcyon Extended, 635N	82·00	206·45
	St. Francis, 773N	212·00	43·90
1909 ..	Halcyon, 313N	55·00	17·03
	Halcyon Extended, 635N	203·50	116·10
	St. Francis, 773N	246·00	25·64
1910 ..	Halcyon, 313N	580·00	109·56
	Halcyon Extended, 635N	105·00	57·16
1911 ..	Do.	16·00	12·61
1912 ..	Do.	245·00	222·59
1913 ..	Commodore North (former 619N), 1201N	16·00	4·64
1914 ..	Halcyon, 1228N	13·00	22·97
	Halcyon Extended, 635N	280·00	94·02
	St. Frances, 1257N	34·00	6·42
	Total	**5,843·00**	**2,879·09**

* Dollied and specimens.

2. *Geology*—(a) *Country;* (i) *Flecked Schists.*—The rock exposed in the shallow western workings is yellow-brown and rarely shows signs of schistosity. However, examination of the sides of shaft XII. from surface to bottom (at 87ft.) shows that the yellow unsheared rock results from weathering of the sheared dolerites or flecked schists (page 69) and this portion of the group has been mapped accordingly.

(ii.) *Black Carbonate Rock.*—East of the West Lode the rocks, though usually much weathered, are pretty certainly the Black Carbonate Rocks of peridotitic origin, which will be mentioned frequently later. Usually they are sheared, but in the small shafts on the Halcyon East (485N) are unsheared.

(b) *Lodes*—(i.) *West Lode.*—This extends for 30 chains from the north boundary of the Commodore G.M.L. to the north boundary of the Commodore North Extended.

In its southern part, this body (which has yielded small quantities of milling-dirt—for example, from the 30ft. level shaft I., shaft V., and 30ft. and 53ft. levels, shaft VIII.), is a fine-grained yellow or sometimes bleached rock with small irregular quartz stringers which are said to carry all the gold. In its northern part it narrows to a few stringers (or only one) from which in shafts XI., XIII., and XIV., a small amount of ore has been won.

The West Lode is thus merely a zone of country more abundantly impregnated with quartz than is usual. Unfortunately, on Plate XIII. it has, owing to the conventions of geological mapping, acquired a prominence of which it is altogether unworthy.

(ii.) *East Lode.*—This body is ascertained to extend from shaft II. (Commodore North) to shaft N, beyond the Halcyon Extended —a distance of about 21 chains.

At the south end (Shaft II.) is found a dyke of light-coloured granite-like rock, which detailed examination proves to be a platy albite porphyry (346C and 73D) (*see* Chapter VII., page 225). Specimens taken across this dyke vary much in composition. This rock is said to yield gold in small quantities. The porphyry near the north end of the Commodore G.M. shows some similarity to this rock and is probably its southern extension.

At the north end, the Halcyon Extended workings follow a dyke (Fig. 22) which, when weathered, agrees in general appearance with that just described, but when unoxidised is a medium or coarse-grained dark green pyritic rock. Microscopic examination, however, proves this to be a chloritised albite porphyry $\left[\frac{1}{308}\right]$ resembling the rock from the south end.

In its middle portion—the Halcyon workings—the lode where accessible, though too decomposed for microscopic examination,

shows a general, but not close, similarity to the oxidised ore from the north and south ends. There is no record of its character in the flooded 250ft. level.

Combining field position and petrological evidence, it is reasonable to link up these separated occurrences into one dyke (the Halcyon) of chloritised albite porphyry.

The gold produced by the Halcyon Group has, except that yielded by the flat vein between shafts A and C, come from small quartz stringers, nearly all confined to the porphyry and either flat, or else transverse to the dyke and dipping steeply north. The few which pass out into the black carbonate rock are said to be richer. Between shafts A and G, the stringers have been rich and numerous enough to render payable the bulking of the lode—as in the open-cut and the "ball-room" off shaft F at the 33ft. level. From shaft H northwards, the stringers are fewer and larger and are followed by small stopes. Here, moreover, the dyke has divided, but the branches are only 10ft. apart and are not distinguished in Plate XIII., Sheet 2. The small exposure in shaft N shows hardly any quartz stringers.

C.—Commodore Group.

Both in position and geology, the Commodore, Ingliston, and Ingliston Proprietary South are distinct from the rest of Paddy's Flat. Their main peculiarities are abundance of fuchsite-carbonate rock without a corresponding development of porphyry, and the contrast offered by their ore-bodies in position and direction of strike and dip to the Paddy's Flat lodes.

Commodore G.M. Co., N.L. (G.M.Ls. 597N and 1041N), (Plate XIII., Sheet 4, and Plates XIV. and XV.).

1. *History, etc.*—A rich vein was found in 1899 on the present Commodore Lease by a prospector named McNab, who, through not using pegs of the statutory size, had to forfeit his claim to G. Dennis. This was the first discovery of gold on the Paddy's Flat Belt. Of the two leases held by the Commodore Co., T. Martin, in August, 1909, applied for the Commodore West, which was bought by the Company from the later occupant, J. Cordner, in July, 1910, from whom they also bought the Commodore, which had been applied for in April, 1905, and covered part of the ground formerly occupied by 283N ("Commodore," J. Judge, G. Dennis and others), 284N ("Commodore North," same lessees), and 384N ("Clean Sweep," N. G. Carberry and J. Beachem), leases which were all taken up between 1899 and 1901.

Although before 1901, in addition to the small quartz vein originally found, the eastern lode of the Commodore had been recognised, most of the prospecting seems to have been done by Cordner and party.

In July, 1910, the Commodore G.M. Co., N.L., was formed. It was only, however, in April, 1912, that the battery (purchased from the Karangahaki Mines, Ltd.) and cyanide plant began work.

Table showing the Yield of the Commodore Ore-bodies.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1900 ..	Commodore and Commodore North, (283N) and (284N)	118·00	356·23
1901 ..	Do. do. do.	297·25	957·15
1902 ..	Do. do. do.	227·25	461·97
1903 ..	Do. do. do.	613·50	362·80
1904 ..	Do. do. do.	519·75	315·71
1905 ..	Do. do. do.	86·00	253·69
1906 ..	Do. do. do.	113·00	262·50
1907 ..	Do. do. do.	117·00	303·42
1908 ..	Do. do. do.	128·00	307·37
1909 ..	Do. do. do.	54·00	141·73
1912 ..	Commodore G.M. Co., N.L., 597N, 1041N	8,321·00	2,543·64
1913 ..	Do. do. do.	11,070·00	3,639·74
1914 ..	Do. do. do.	9,020·00	3,320·55
	Total	**30,684·75**	**13,226·50**

2. *Equipment.*—The winder and Worthington pump are supplied with steam from a Cornish boiler.

The 10-head mill, 3 drill-compressor and dynamo are driven by two (50 h.p. and 52 h.p.) Hornsby gas-engines, gas being supplied by a Commonwealth wood producer.

Water from the three upper levels is pumped out, that from No. 4 level is baled. About 20,000 gallons, mainly from the west lode, comes from the mine every 24 hours and is ample for all requirements.

The ore is trucked about 40 yards from the mouth of the shaft to the rock-breaker.

Further details of treatment are given in Chapter II.

It is stated that on November 30, 1914, 13,660 long tons of slimes of average value 15s. 4d. had been accumulated for further treatment.

Costs per long ton including mining, treatment, and realization of bullion, averaged for the year ending November 30, 1914, £1 1s. 7d.

3. *Geology* (*see* Plate XV.)—(a) *Country;* (i.) *Talc-Chlorite-Carbonate Rock.*—In hand specimens this rock is, when unweathered, generally green or grey-green, and in places is strongly sheared. Its doleritic origin is discussed in Chapter VII. (page 266).

(ii.) *Fuchsitic Rocks.*—Hand specimens of these are characterised by their green colour, which varies in brightness according to the amount of fuchsite. Typical specimens are finely granular, but near the talc-carbonate rocks, transitional stages are common. In places on the No. 1 level, the rock is surprisingly little weathered, considering its highly decomposed state west of the East Lode at No. 3 level, which again contrasts with its freshness east of the East Lode at this level.

The probably doleritic origin of these fuchsitic rocks is discussed in Chapters IV. and VII. (page 272).

(iii.) *Chloritic Slates.*—These are recognised only at the south-west end of No. 3 level. In hand specimens, they are rather soft dull greyish-green slaty rocks, imperfectly fissile. Details are given on pp. 70 and 259-61.

(iv.) *Chloritised Albite-Porphyry.*—The characters of this rock $[\frac{1}{101}, \frac{1}{356}]$, discussed on pp. 225-7, indicate relationship to the Halcyon, rather than to the Paddy's Flat porphyry. It has been found only on No. 3 level, where there is a mixture of fuchsite rock and porphyry, and where the boundaries are by no means as clear as the plan (Plate XV.) indicates. A white clay occurring in the old "intermediate" level below No. 1 level shows, contrary to general belief, no sign of porphyritic origin.

(v.) *Chief Determinations of Commodore Rocks.*—The following statement shows the petrological determinations of most of the rocks examined from this mine:—

Specimen Number.	Locality.	Determination.
$[\frac{1}{101}]$	No. 3 Level ..	Very acid phase of quartz porphyry magma.
$[\frac{1}{141}]$	No. 4 Level ..	Quartz-carbonate-fuchsite rock.
$[\frac{1}{146}]$	Do. ..	Chlorite-carbonate-albite(?)quartz rock.
$[\frac{1}{147}]$	Do. ..	Quartz-carbonate-albite(?)fuchsite rock.
$[\frac{1}{148}]$	No. 3 Level ..	Like $[\frac{1}{204}]$, but finer grained, partly oxidised perhaps albite is present.
$[\frac{1}{149}]$	Do. ..	Quartz-carbonate-fuchsite-albite rock.
$[\frac{1}{150}]$	Do. ..	Chlorite-albite-carbonate-quartz rock.
$[\frac{1}{151}]$	Do. ..	Fuchsite-carbonate-chlorite-quartz-albite(?)rock
$[\frac{1}{152}]$	No. 4 Level ..	Fine granular carbonate-fuchsite quartz rock.
$[\frac{1}{179}]$	No. 3 Level ..	Talc-chlorite-carbonate rock.
$[\frac{1}{199}]$	Do. ..	Chloritic slate very finely laminated.
$[\frac{1}{200}]$	Do. ..	Chloritic slate.
$[\frac{1}{204}]$	Do. ..	Sheared chlorite-carbonate rock.
$[\frac{1}{355}]$	Do. ..	Like a fuchsite quartz carbonate rock without the fuchsite.
$[\frac{1}{356}]$	Do. ..	Highly carbonated albite porphyry.
[75d]	No. 1 Level ..	Minutely scaly chlorite-talc mass.
[76d]	No. 4 Level ..	Chlorite-carbonate-quartz schist.

(b) *Ore-Bodies and Fissures.*—The two chief ore-bodies are considerably affected by several cross-veins and faults.

(i.) *The West Lode* has yielded the greater quantity of shallow level ore. It is a quartz vein deposited along, but not always filling, a fissure which is parallel to the shear-planes, but dips west steeply.

Fig. 50.

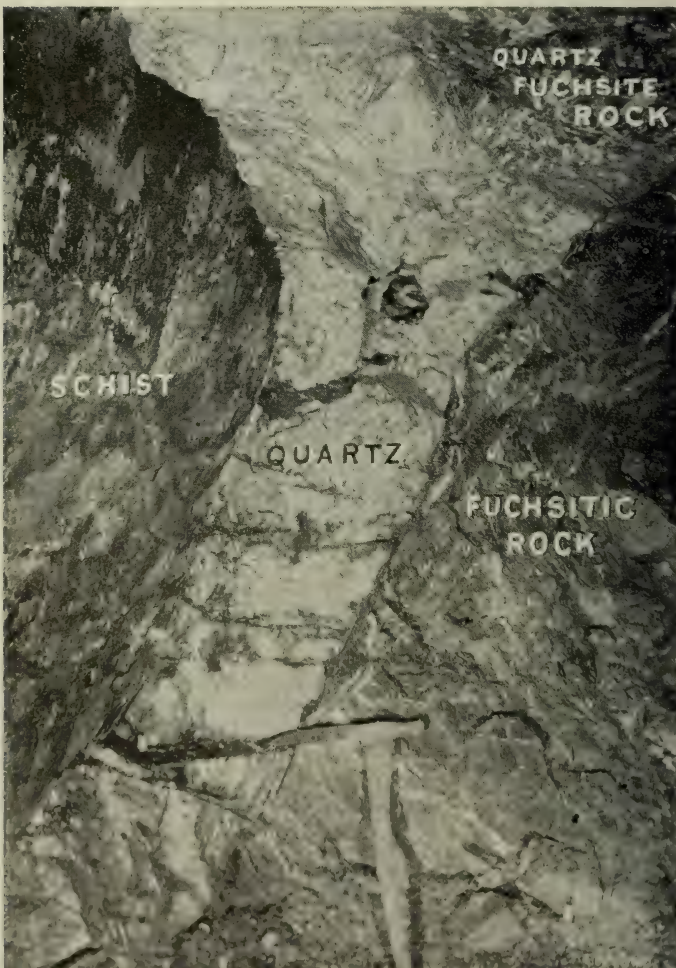


Photo. E. de C. Clarke. Neg. 1419.

Relation between Fuchsite Rock and Schist, Commodore G.M., No. 4 Level, north end (January, 1915).

At places in No. 2 and 3 levels, it is thought to divide. At the south end, the fissure, which has been followed for some distance in the slates, is poorly defined and is indeed probably displaced by the south fault (*see* below). The wrong "track" has been followed north of the sulphide spur on No. 3 level and results have been unsatisfactory in this part of the mine.

(ii.) *The East Lode*, which is a quartz vein varying from a few inches to 3ft. in thickness, accompanied by many stringers, which net the country (*see* Figs. 50 and 51), dips west at angles

Fig. 51.

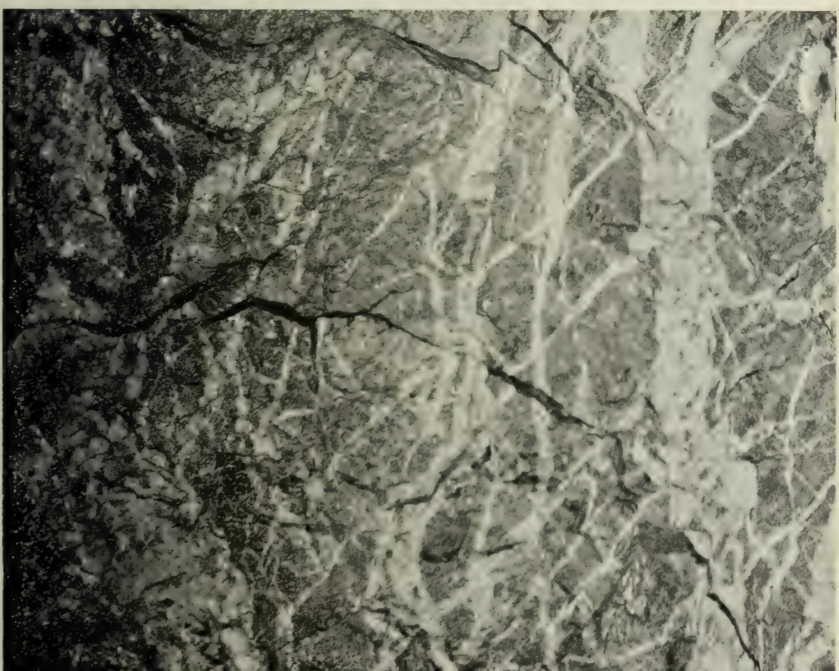


Photo.: E. de C. Clarke. Neg. 1418.

Fuchsite Rock netted with Quartz. Same locality as Fig. 50.

varying from 60° to 80°. In No. 1 level, those parts of it explored lie in the talc-carbonate rock, but in No. 3 level, it is partly in the fuchsite, partly in the transitional rock, and the bulk of the ore has come from the parts enclosed by the latter, although dabs of payable

ore have been found in fuchsite country. In No. 4 level, the East Lode lies at the junction of fuchsite and talc-carbonate rock and is very patchy.

(iii.) *Cross Veins and Fissures.*—The South Fault strikes about 10° W. of N. and dips east at 80° or more. It is seen crossing the east lode-channel at levels 1, 3 and 4, and probably cuts the West Lode-fissures at No. 1 level as shown. The continuation of the ore-bodies south of this fault has not been satisfactorily located, and in No. 3 level values are said to disappear 20 feet north of it.

The *Main Spur* is a small quartz vein which abuts on the East Lode at 45ft. south on No. 3 level and gave rich values above that level, but the shoot constantly narrows and probably does not exist much above No. 1 level, nor has it been found at No. 4. Its strike is at right angles to that of the South Fault and it dips N.W. at 40° to 60°. The main East Lode yields but little gold near its contact with the Main Spur.

Fourteen tons of quartz averaging 6oz. per ton came from a very small spur on No. 3 level, 100 feet north of the Main Spur.

The *Sulphide Spur* running off the West Lode at 60 feet north in No. 2 level has been worked down to No. 3 level. It dips north at 60°. The mixture of fuchsite rock and chloritised albite porphyry enclosing this vein is rich in pyrite, hence the name.

The *Spur* found on No. 1 level about 120 feet north, strikes parallel to the main bodies, but dips east at 70° or more.

The *Branch Vein* on No. 1 level at about 300 feet north, results from the splitting of the West Lode about 40 feet above the level.

The *North Spur* is probably the first auriferous body found on the Paddy's Flat Belt, and, judging by the earliest returns from the Commodore, was rich.

The *New Spur* found in 1914 lies almost wholly in decomposed fuchsite rock and dips north at a very low angle. Like the other spurs, it was rich, but small in extent.

It must also be noted that "A" shaft (near the northern boundary of the lease) is said to have yielded prospects from a schistose rock. The mode of occurrence is said to resemble that of the Ingliston Extended East Lode, of which, however, it is not the continuation.

The Ingliston G.M. (Plates XIII., Sheet 4, and Plates XIV. and XV.).

1. *History, etc.*—Butler and party discovered gold on the Ingliston (G.M.L. 363N) in 1900, in October of which year they applied for the lease. It was subsequently held for a short time by another party under the name of "Commodore Block" (555N). Butler and

party regained possession, and, after crushing a considerable quantity of ore at the State Battery, erected a 10-head mill, which began work early in 1915. The mill, rock-breaker and accessories are run by a 90-h.p. Tangye gas-engine supplied from a 120-h.p. Akroyd producer. The mine is also provided with a boiler and winder.

Tailings are being stacked pending erection of a cyanide plant.

Although work, before machinery had been erected, was hampered by inflow of water, this was expected to be insufficient for the plant, and the mine is connected with the Mines Water Supply scheme.

Table showing the Yield of the Ingliston Gold Mine.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1901 ..	Ingliston, 363N	114·00	224·04
1902 ..	Do.	182·50	194·08
1903 ..	Do.	50·50	39·22
1905 ..	Ingliston, 555N (former 363N) ..	120·00	609·54
1906 ..	Do. do.	119·00	324·57
1907 ..	Do. do.	40·00	88·71
1911 ..	Do. do.	357·44	184·43
1912 ..	Do. do.	132·95	209·71
1913 ..	Do. do.	433·10	915·31
1914 ..	Ingliston Leases 555N and 1239N ..	610·85	969·38
	Total	**2,160·34**	**3,758·99**

2. *Geology*—(a) *Country.*—The only recognisable rock in these workings at the time of the writer's visit was carbonate-fuchsite rock of the Commodore type, which showed, as in the Commodore, alternating decomposition and freshness in the lowest (200ft.) level. In the upper levels it is highly decomposed in the usual way.

(b) *Ore-bodies.* (i) *Main Ore-body.*—Like the Commodore East Lode, this is a quartz vein—at the north end a system of veins—which varies in thickness from a few inches to three or four feet, strikes about 10° west of north, *i.e.*, parallel to the Commodore's South Fault, and dips west at about 70°. The quartz of the Main Ore-body is, like that of the Commodore East Lode, dense and white, with fuchsitic inclusions.

In its south part the Main Ore-body runs straight, but at the north end several veins crossing one another at various angles have been mined. In this part, the ore, though occasionally rich, was erratically distributed.

The fairly continuous south shoot (*see* stope-section, Plate XIV. —the shoot is 300 feet long, 4 feet wide, and is said to average 12 dwt. per ton) is, according to the miners, caused by the numerous small quartz leaders, which cut into the main channel from the west and enrich it.

(ii) *East Lode.*—This, which has been opened out since the writer's visit, has the same character as the Main Ore-body, but strikes about 10° east of north. It crosses the Main Body about 80 feet south of the Central Shaft, is probably continuous with the Commodore East Lode, and may be expected to prove the most important and persistent of the Ingliston ore-bodies.

(iii) *Flat veins.*—No. 1 Flat Vein was found in sinking the Main Shaft; No. 2 has been discovered since the writer's visit.

No. 1 strikes about N. 40° E. and dips N.W. at angles of between 20° and 30°. No. 2 strikes about N. 60° W. and dips N.E. at about 20°. Usually these veins are only a few inches thick and are of rather glassy quartz containing green-stained vughs. Immediately surrounding the vein is a green sericitic layer which is frequently gold-bearing. The country is exceedingly weathered fuchsite rock. In about six places a steep or vertical head runs down from the footwall of No. 1 vein and carries very rich "face gold" but no quartz (*cp.* Globe G.M., p. 167).

In a general way, the Ingliston Flat Veins are similar to the spurs at the north end of the Commodore G.M.

INGLISTON PROPRIETARY SOUTH (1202N) (Plate XIII., sheet 4.)

1. *History, etc.*—This lease was originally pegged (as 554N Ingliston Central) by J. F. Butler in 1904, and successively held by five other parties. S. J. Brosnan was in occupation at the end of 1914. The work done on the adjoining leases to the west and south is too insignificant to call for notice.

Table showing the Yield of the Ingliston Proprietary South Leases.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1906 ..	Ingliston No. 2, 514N	30·50	21·52
1907 ..	Commodore Extended, 660N ..	32·00	3·99
	Ingliston No. 2, 514N	31·00	32·53
1913 ..	Ingliston North, 902N (former 514N) ..	10·00	25·05
	Total	**103·50**	**83·09**

2. *Geology.*—The rocks being exceedingly weathered, field identifications were relied on for mapping. In the eastern part, chlorite-carbonate rock of doleritic origin and fuchsite rock occur. These give place in the west to chloritic slates and flecked schists like those of the Queen of the Hill Mine (p. 168).

The workings on payable quartz (shaft 7) were put down after the writer's examination of the locality. They are reported to be on a flat vein similar to those of the Ingliston G.M.

The "lode material" (small irregular quartz stringers forming a network in the coarse gritty decomposed fuchsite rock) shown on 90ft. level, shaft 4, is said to have given a crushing averaging 5 dwt. per ton.

VIII.—MAIN SECTION OF PADDY'S FLAT BELT.

A strip about two miles long and a quarter of a mile wide, extending from the Macquarie North (734N) S.S.W. to the Judy (925N), constitutes this section, from which 376,560.18 tons of ore have yielded 283,184.62 fine ounces of gold. Most of this strip is in a shallow valley near the head of a watercourse draining ultimately into Lake Annean. There are no outcrops of any significance —even when "Paddy" Donovan first prospected in the "Flat" named after him, probably no rocks except boulders of quartz and "ironstone" were to be seen.

Between the south end of the section under discussion and the Globe G.M. is a tract of more broken country in which are some outcrops of recognisable rock.

A.—Macquarie Leases (915N and 734N).

(Plates XIII., sheets 4 and 6, and XIV.)

1. *History, etc.*—This ground—the Macquarie was first leased to H. Campbell and J. A. Osborne in September, 1903, as the "Lost Cop" (488N), and was held successively as the "Brown Hill" and "Commodore Brown Hill" by other parties—has been chiefly explored by Kearns Bros. and party, who took up the two leases in 1907 and have worked them almost continuously since. In 1914 an Adelaide syndicate erected poppet legs, winding gear, etc., sank a new main shaft to 210ft., and cross-cut to the lode, but then stopped work.

Table showing the Yield of the Macquarie Leases.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1903 ..	Lost Cop, 488N	56·00	18·48
1904 ..	Do.	24·00	14·02
1904 ..	Brown Hill, 532N (former 488N) ..	15·00	4·06
1906 ..	Commodore Brown Hill, 641N (former 532N)	136·00	29·85
1907 ..	Macquarrie, 728N (former 641N) ..	594·50	157·41
1908 ..	Do. do. ..	2,465·50	450·43
	Macquarrie North, 734N	59·00	10·48
	Do.	..	*7·63
1909 ..	Macquarrie, 728N	991·50	172·79
	Macquarrie, 915N (former 728N) ..	591·00	100·70
1910 ..	Do. do. do. ..	1,222·00	152·41
1911 ..	Do. do. do. ..	1,310·88	539·22
1911 ..	Macquarrie North, 734N	..	*22·22
1912 ..	Macquarrie, 915N	572·25	272·93
	Macquarrie North, 734N	26·25	14·60
1913 ..	Macquarrie, 915N	91·85	32·26
	Do.	..	*2·07
1914 ..	Do.	—	1·69
	Do.	..	*3·63
	Total	**8,155·73**	**2,006·88**

* Dollied and specimens.

2. *Geology.* (a) *Country.* (i) *Black Carbonate Rock.*—The north part of the Macquarie workings is in black (brown when weathered) rock, so clearly massive that it is usually mistaken for dolerite of the Ingliston Extended type. It is traversed by joints and shear-zones, of which the strongest run nearly north and south, while others strike across them obliquely. Microscopic examination proves this to be a talc-chlorite-carbonate rock of peridotitic origin.

(ii) *Sheared Doleritic Rocks.*—The extremely weathered rock, outcropping and underground in the south part of the Macquarie Lease, in minute structure resembles rather rocks of doleritic than of peridotitic origin.

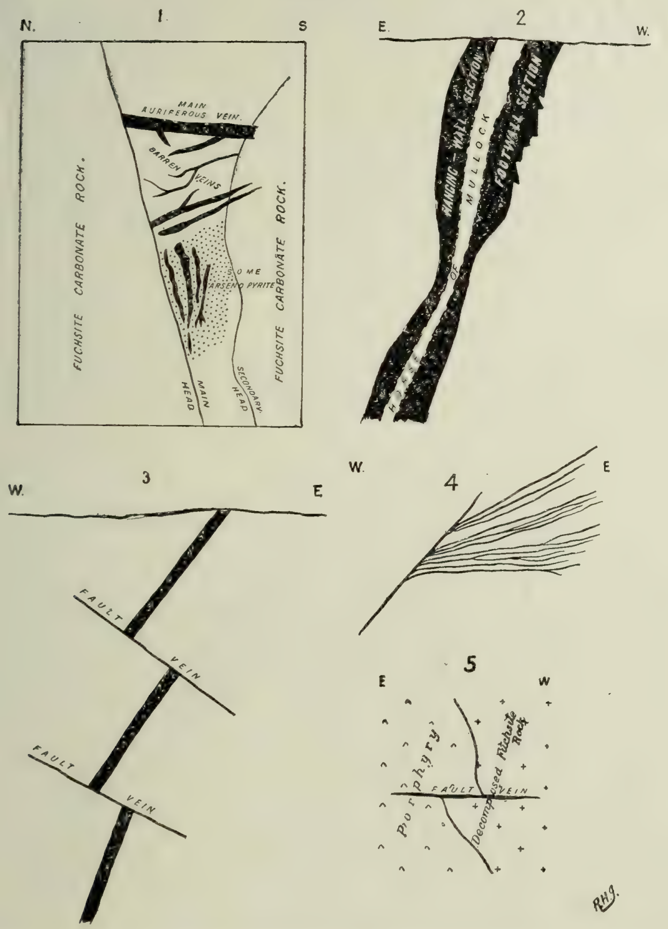
(b) *Lode.*—The lode may, from its position (*see* Pl. XIII., sheets 4 and 6), be regarded as the continuation of the Ingliston Extended East (or "Mud" Lode. It is unduly prominent on Pl. XIII. (*cp.* Halcyon West Lode, p. 132).

The branching is shown near the south shaft on the authority of the owners. No. 2 south shaft is considered by them to be on the south edge of a north-pitching shoot.

The lode usually dips steeply east, but in places it is practically vertical, and in others dips west.

The lode material—everywhere decomposed—is brown and gritty and not unlike a fine-grained variety of weathered fuchsite

Fig. 52.



Sections illustrating Features in Workings near Meekatharra.

1. Globe G.M.: Relation of veins and fuchsite rock. Scale: 8ft. = 1in.
2. Macquarie G.M.: Diagrammatic cross-section of lode.
3. Globe G.M.: Supposed structure of ore body. (Diagram.)
4. Gwalia Extended G.M.L.: Shaft F—three groups of quartz stringers united to form a rich vein. (Diagram.)
5. Gwalia Extended G.M.L.: Shaft H—Relation between flat vein, porphyry, and fuchsite rock. Scale: 8ft. = 1in.

rock. Quartz veins, when present, are very small; the largest—6 inches thick—is on the hanging-wall of the lode just south of No. 1 North Shaft.

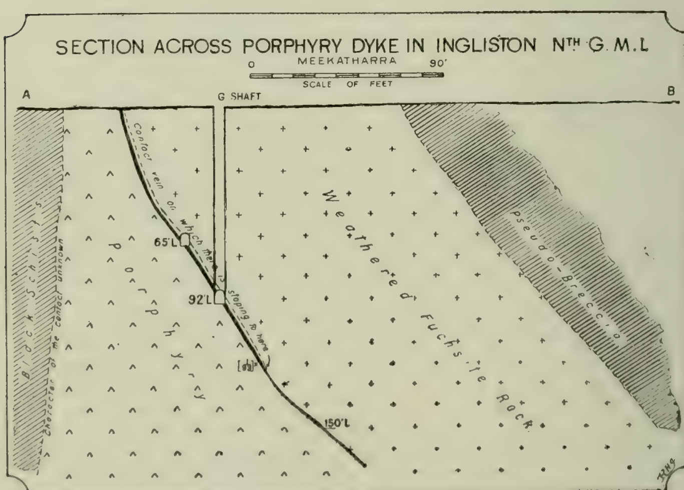
Most consistent values are said to be along the footwall, where the ore is redder than elsewhere. Good ore is also found frequently, but not so consistently, on the hanging-wall. Between hanging- and footwall lode-matter is a zone of lower grade country which has almost escaped mineralisation.

The footwall, which is the most clearly marked of the numerous shear-planes, shows many irregularities, in places becoming the hanging-wall. Moreover, the ore cuts into the country along minor joints, so that, when stoped out, a stair-like footwall is left (Fig. 52).

B. Ingliston North G.M.L. (514N) (Pl. XIII., sheet 6).

1.—*History.*—This lease, pegged early in 1904 by J. Fleming and W. Wallshaw, and worked by them for five years, is now held by S. J. Brosnan.

Fig. 53.



2. *Geology.* (a) *Country.* (i.) *Flecked Schist.*—Hand specimens from this lease have the pseudo-breccia character found both in peridotitic and doleritic rocks in the Belt, but are shown by their micro-structure to be doleritic. They are usually strongly sheared,

but whereas in the 78ft. level (shaft J) shearing is marked, in the bottom level, almost directly below, the rocks appear to be unsheared. As the flecked schist or pseudo-breccia nears the porphyry dyke it becomes brown and gritty and stained light green. At greater depth this altered zone would probably become fuchsite rock. On the eastern side of the porphyry this alteration does not take place.

(ii) *Dolerite.*—In the east cross-cut (H shaft) a spheroidally weathered rock is, both from position and appearance, to be regarded as the Ingliston Extended dolerite.

(iii) *Porphyry.*—This, the northernmost occurrence of the Paddy's Flat Dyke, is irregular both in plan and section* (Fig. 53).

(b) *Ore.*—Any ore taken from this lease has apparently come from a small quartz vein lying on the south-west edge of the porphyry and struck at 40ft. in F shaft.

A number of quartz stringers, probably the continuation of the Ingliston Extended West Lode, are met in the crosscut off A shaft. No attempt to prospect this promising occurrence has been made.

C. Ingliston Extended Group. (Pls. XIII., sheets 5, 6, and 7, XIV. and XV.)

The Ingliston Extended North (437N), New Ingliston (529N), Ingliston Extended East (462N), Ingliston Extended (398N), Manchuria (881N), Ingliston United (507N), and Ingliston South Extended (520N) form this Group. Interest centres round the workings of the "Ingliston Extended Gold Mines, Ltd.," which holds 398N, 437N, 462N, 529N, 847N, 881N, and 1033N.

1. *History, etc.*—The Eastern ("Mud") Lode was found by Uriah Wright, who, in August, 1901, with others pegged the Ingliston Extended. Most of the early work seems to have been done by C. and J. Roberts, who worked the East Lode down to the 100ft. level and crushed 1,100 tons for 1,000 oz., tailings yielding an additional 16 dwt. per ton. In 1905 the Ingliston Extended and neighbouring leases were taken over by the Company, which by the end of 1906 had a 10-head mill and cyanide plant—the first privately owned treatment-plant at Meekatharra—in operation. In 1907, the West Lode, which had been discovered close to the surface two years before, was located in a 50ft. shaft, 185 feet west of the Mud Lode. To mine the West Lode, avoid the dolerite in which the old main shaft had been sunk in 1905, and catch the north-pitching shoots of the Mud Lode, the Faithful shaft was then sunk, and from it all mining has since been conducted.

* The porphyry is highly decomposed.

The Ingliston Extended North and Ingliston Extended East were originally taken up by J. A. and C. M. Roberts. The former lease contains nearly all the Company's later workings.

The Manchuria, part of which had been previously held, was pegged by the Company in 1909, and has since been unsuccessfully prospected for the West Lode.

The Ingliston United, first leased in 1904 to W. Hammond and party, passed through a number of hands. C. M. Roberts and party did most of the shallow-level prospecting and defined the porphyry and dolerite dykes, although the character of the latter was not recognised.

In the beginning of 1911 an option held by S. J. Yeo was transferred to the Oroya Exploration Co., Ltd. During these options the bulk of the deeper exploration off the main shaft was done. The long east cross-cut was put out (after failure to locate any body of ore on the east wall of the porphyry by winzing) in hope of cutting the Ingliston Extended East Lode.

The Ingliston South Extended is also now held by the Oroya Exploration Co. It was first prospected in 1905, and the chief work (except the deep cross-cut already mentioned) appears to have been done by W. C. Smith and party in 1906 and 1907. Small veins only, and no defined ore-body, were found in the peridotitic rocks bordering on the dolerite dyke.

Table showing the Yield of the Ingliston Extended G.M.

Year.	Name and Number of Lease.	Ore csushed.	Gold therefrom.
		tons.	oz.
1902 ..	Ingliston Extended, 398N	307·00	340·27
1903 ..	Do. do.	854·25	609·82
1904 ..	Do. do.	159·00	156·37
1906 ..	Ingliston Extended G.Ms., Ltd. (amalgamated leases 398N, 437N, 462N, 529N, 539N, 847N, 881N, 1033N)	7,773·00	4,547·46
1907 ..	Do. do. do. ..	14,950·00	6,280·34
1908 ..	Do. do. do.	16,816·00	6,338·64
1909 ..	Do. do. do.	9,021·00	4,025·94
1910 ..	Do. do. do.	8,531·00	6,260·67
1911 ..	Do. do. do.	9,226·75	6,546·98
1912 ..	Do. do. do.	7,008·20	4,687·16
1913 ..	Do. do. do.	6,590·00	3,665·56
1914 ..	Do. do. do.	9,205·00	5,114·88
	Total	**90,441·20**	**48,574·09**

Table showing the Yield of the Ingliston United and Ingliston South Extended Leases.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1904 ..	Ingliston United, 507N	70·25	72·40
1905 ..	Do.	38·00	16·39
1907 ..	Do.	176·00	48·96
1908 ..	Do.	9·00	10·20
1908 ..	Ingliston South Extended, 520N ..	10·00	10·60
	Total	**303·25**	**158·55**

2. *Equipment and Treatment on the Ingliston Extended G.M.** —Two Cornish boilers supply steam for the winder and air-compressor. A 72 h.p. Crossley gas-engine drives the 10-head mill and a 38 h.p. Hornsby the slimes plant.

The battery being near the old main shaft, the ore is now, after passing through the rockbreaker at the Faithful shaft, trucked about 100 yards to the mill, where the trucks are hoisted and emptied into the ore bin.

It is stated that there is no reduction in residues by grinding finer than 60-mesh. From the grinding-pans the pulp is passed over two Wilfley tables, where the concentrates, which average .8 per cent. of the total pulp, are collected.

Sands are given a five days' percolation treatment. Slimes are treated in a filter press.

3. *Geology*—(a) *Country.*—The rocks of this group show variety in structure and composition, and belong to three groups:—

(i.) *Black Schists.*—These rocks, which are sheared peridotites, predominate in the east part of the workings, and in them occurs the East Lode. Though traversed in many places by shear-planes, hand-specimens are generally not markedly schistose. They resemble the black carbonate rocks of the Macquarie, without the irregular flecks and fragments. Further discussion of these rocks will be found in Chapters IV. and VII.

(ii.) *Fuchsite-Quartz-Carbonate Rocks.*—These are also discussed in Chapters IV. and VII., and their distribution in the Ingliston Extended Mine may be seen in Plates XV. and XIX.

(iii.) *Porphyry.*—The Paddy's Flat Porphyry Dyke is well exposed in the western workings of this mine—its course is shown on Plate XV. Below about 80ft., the porphyry has in the northern workings a nearly vertical slickensided eastern face, which forms

*Further detail will be found in Chapter II.

the west wall of the West Lode.. Above the 80ft. level, this face is sliced off by a fault, mentioned below.

(iv.) *Dolerite.*—Throughout the Ingliston Extended Mine, this rock is in contact with the Black Schists along an almost vertical plane. Its intrusion was later than the shearing period and the injection of gold-solutions.* It maintains its south-west course to shaft C (507N), where it turns west, cuts through the porphyry and lode-channel and then turns south, passing through the Fenian West (963N), and is last seen in No. 3 shaft of 962N. Throughout its length the dolerite has only been found outcropping in three or four places, in all of which it is exceedingly weathered—as also are the underground specimens on the microscopic character of which its extension through the Fenian West to 962N has been mapped. The mapping of this part of its course is, therefore, doubtful, although microscopic work and mode of occurrence combine in indicating its correctness, as they also do in denying its generally supposed extension, on the continuation of its strike in the Ingliston Extended, to the east of the Consols Group (*see* above, p. 72).

(v.)—*Chief Determinations of Ingliston Extended Rocks.*

Specimen Number.	Locality.	Determination.
$[\frac{1}{85}]$	425ft. Level ..	Albite-quartz porphyry.
$[\frac{1}{86}]$	Do. ..	Quartz porphyry.
$[\frac{1}{135}-\frac{1}{137}]$	Do. ..	Black schist (sheared peridotite).
$[\frac{1}{138}]$	Do. ..	Black schist.
$[\frac{1}{139}]$	Do. ..	do.
$[\frac{1}{143}]$	Do. ..	Junction of black schist and dolerite.
$[\frac{1}{145}]$	300ft. Level ..	Black schist.
$[\frac{1}{154}]$	425ft. Level ..	Fuchsite-quartz-carbonate rock.
$[\frac{1}{155}]$	Do. ..	Chlorite-carbonate-quartz rock.
$[\frac{1}{157}]$	Do. ..	do. do.
$[\frac{1}{159}]$	Do. ..	Talc-chlorite-carbonate-quartz rock.
$[\frac{1}{181}]$	300ft. Level ..	Brownish-red fuchsite rock.
$[\frac{1}{190}]$	637N, Shaft B.	Chloritic talcose serpentine.
$[\frac{1}{219}]$	300ft. Level ..	Talc-chlorite schist .
$[\frac{1}{220}]$	210ft. Level ..	Dolerite.
$[\frac{1}{221}]$	300ft. Level ..	Talc-chlorite-carbonate rock.
$[\frac{1}{222}]$	Do. ..	Flecked talc-chlorite-carbonate serpentine.
$[\frac{1}{223}]$	Do. ..	Sheared talc-chlorite-carbonate serpentine.
$[\frac{1}{224}]$	425ft. Level ..	do. do. do.
$[\frac{1}{225}]$	Do. ..	Talc-chlorite rock with rutile.
$[\frac{1}{226}]$	Do. ..	Cp. $[\frac{1}{135}]$ and 499c (Macquarie).
[illegible]	729N Shaft ..	Chloritic talcose serpentine.
[5d]	507N, Shaft C.	Much weathered dolerite.
[6d]	507N, Costeen..	Dolerite ?.
[80d]	637N, Shaft 4 ..	Chloritic talcose serpentine.
[221c]	425ft. Level ..	Dolerite.

* Mr. W. J. Turner has informed the writer that an offshoot of the dolerite was seen in one stope cutting through the lode.

(b.) *Lodes.*—(i.)—*East Lode.*—This deposit has been followed 1,200 feet horizontally, and 500 feet vertically, but is not payable throughout. It has yielded the bulk of the gold produced by the Ingliston Extended Mine. Its walls are ill-defined and tongues of payable ore diverging from the main body are easily overlooked. The shoots pitch north at rather flat angles.

The East Lode is a sheared zone in the black schists, which has been permeated by gold-bearing solutions. The dull greenish quartz stringers form a small part of the total bulk of the lode, which owes its name, "Mud Lode," to the readiness with which the oxidised ore slimed in the battery.

The East Lode has not been proved to be affected by any transverse faulting, but a possible strike fault occurs in it near its north end.

Throughout its greater part the East Lode lies close to the dolerite, which, as stated above, is of later date. If, therefore, the strike or dip of the dolerite is, in the course of further exploration, found to alter, and, concurrently, the East Lode to pinch out, the latter will probably be found again on the other side of the dolerite. There is no evidence that the lode will be affected by the dolerite in any except this mechanical manner.

Occasional values were obtained in shaft 4 (637N), in Shaft E (65ft. level), and in Shaft B (44ft. level), in which last place one or two quartz veins were mined up to the edge of the dolerite and where values are said to have averaged 1oz. per ton. These may be the southern extension of the East Lode, but this part of the Belt has yielded little more than 10 tons of ore and the occurrence can hardly be called important.

In the Ingliston United Main Shaft values were obtained on the east edge of the porphyry. It is reported also that a "lode formation" was cut at the end of the long east cross-cut. It seems unlikely that the East Lode, which must here be crossed by the dolerite dyke and, consequently, much disturbed, can be successfully mined in this part. Some payable ore might, however, be obtained by finding the lode channel at the south end of the Ingliston Extended open-cut and exploring it southwards at a depth of about 50 feet.

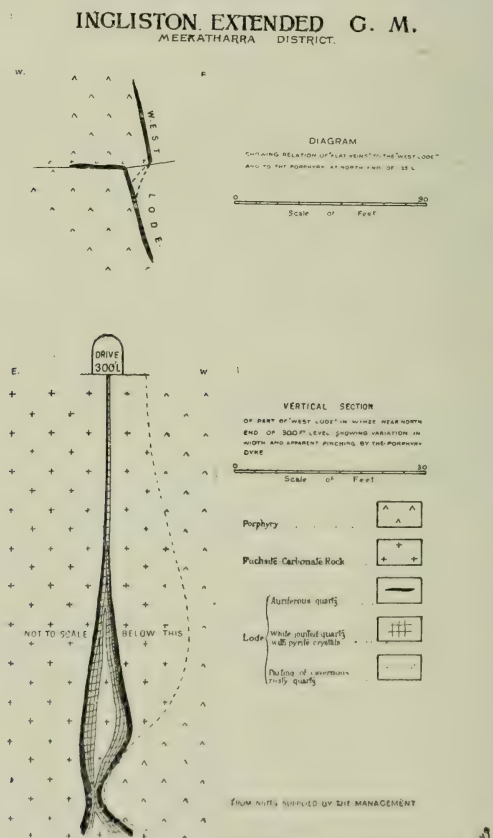
The workings off Shaft D consist mainly of drives along both walls of the porphyry. Small quantities of ore have apparently been obtained, especially from the 40ft. level, to the east of the dyke —below which level there are clear boundaries between porphyry, "lode" (about five feet of quartz-impregnated rock), and schists. This "lode" shows more resemblance to the Ingliston Extended East Lode than to the West Lode.

A similar "formation," apparently of little value, lies against the west side of the porphyry. Through lode and porphyry steeply inclined quartz stringers run uninterruptedly, but are themselves cut by flat stringers in the porphyry.

(ii.) *West Lode.*—This has been followed horizontally for more than 500 feet, and to a depth of more than 400 feet. It dips, sometimes east sometimes west, at very high angles.

The gold-bearing material is quartz, which follows the eastern slickensided wall of the porphyry dyke, and varies from a mere "skin" to three feet or more in thickness (in which latter case, it has a compound structure—fig. 54). Most of the gold comes from a seam

Fig. 54.



of bluish quartz, seldom more than two inches wide, which lies nearest to the porphyry. Occasionally the vein splits and the two parts may be separated by several feet of country, but reunite lower down.

Near its south end, the upper part of the West Lode has been thrown up and west and removed by denudation. Small irregular veins ("contact veins" of Pl. XV.) run along the fault plane, which also cuts through the porphyry.

The southern continuation has been looked for unsuccessfully in the 210ft. level and in Shaft III. (881N). The junction of porphyry and fuchsite rock in Shaft III. is of the dovetail type illustrated from the Gwalia Extended and Mickey Doolan Leases in Pl. XIX. Two crosscuts at the 156ft. level to the west side of the porphyry found no lode matter.

(iii.) *Spurs.*—The spur veins are associated with the West Lode.

South Spurs.—Some rather intricate, almost inaccessible workings, not shown on the plans accompanying this report, lie above the 125ft. level, west of the Faithful Shaft. They appear to have been on small, rather erratic veins, whose strike averaged east and dip north at 40°.

Main Spur.—This body resembles the East Ore Body of the Commodore G.M. in character. It strikes parallel to the West Lode, and is almost vertical. It is composed of three feet to six feet or more of very white quartz, in which are embedded large fragments of the surrounding fuchsite country. The Main Spur is thrown west by the fault already mentioned in connection with the porphyry and West Lode, and its upper portion is supposed to be the "vertical vein" formerly worked about 40 feet above the 125ft. level, the quartz of which is said to have been very like that of the Main Spur.

The Main Spur has yielded a small quantity of ore mainly from a north-pitching shoot which was caused by the junction with the "Sub-spur" Vein. Values are said to be generally better close to the fuchsite inclusions.

Flat Spurs.—At least three spurs have been mined towards the north end of the 125ft. level. One, which cut and faulted the porphyry (diagram in Fig. 54)* yielded rich ore from the part enclosed in this rock. On the other hand, the auriferous quartz of a similar vein 40 feet lower, and a small, rich, "sandy" vein in the same neighbourhood, lay outside the porphyry.

(c) *Faults.*—Apart from the faulting and other movements responsible for the formation of the two lode-channels and of the various spurs, two faults in the Ingliston Extended may be described:—

The north-and-south-striking fault already mentioned as responsible for the faulting of porphyry, West Lode and Main Spur is the older. Evidence for its existence is seen in the stope above the

* This information and the diagram are from Mr. W. J. Turner.

300ft. level, where the main spur is cut off abruptly, and on and above the 125ft. level. Small auriferous veins have been deposited along this plane, which is probably only a little later than the main gold injection.

A later fault is seen in the south-west workings on No. 1 level. In a corresponding place at the 300ft. level disturbed country but no decided fault plane is met. This fault strikes west of north and dips south-west at 70°. It is said to have affected the water-level, which stood at 156 feet in the north and at 110 feet in the south workings.

D.—Consols Group (Plates XIII., Sheets 7 and 8, XIV. and XVI.)

This includes the Ingliston Consols Extended (475N), Fenian (477N), Marmont (481N), Marmont Extended (580N), Ingliston Consols South (544N), Mickey Doolan (589N) and Mickey Doolan East (1149N) leases. Adjoining leases will also be mentioned occasionally. To the end of 1914, 277,660 tons of ore have been treated from this Group for a return of 232,445.10 ounces of fine gold.

1. *History, etc.—Ingliston Consols Extended G.M. Syndicate.*—This syndicate of six members now holds leases 475N, 515N, 729N and 822N. The first lease on this ground and on the Group was the Ingliston Consols (400N) for which P. W. Donovan, J. Murphy, and three others applied in September, 1901, and which they held for less than a year.

In July, 1903, Roberts Bros. cut a 3oz. leader in a prospecting cross-cut at a depth of 30 feet (present No. 3 shaft), and applied for the Ingliston Consols Extended lease.

In 1906, the State Mining Engineer (Mr. A. Montgomery) expressed the opinion that the quartz veins, then regarded as the only material worth mining, were merely part of a larger lode formation, but it was only in April, 1908, when the "chloritic schists" of the 250 feet plat was found to be "studded with gold" that this was generally recognised.

Early in 1909, a five-head mill was working on the lease. The equipment of the mine has been steadily added to, and at present includes a Cornish boiler supplying steam to the winder and to a small dynamo, two 60 h.p. coupled Crossley gas engines and one 62 h.p. Crossley supplied from a Crossley charcoal and an Akroyd wood-producer. The gas engines serve the 15-head mill, cyanide plant, large dynamo, etc.

This mine does not use machine drills.

After passing the mill, the treatment is much the same as in the Ingliston Extended except that slimes, of which about 50,000 tons

averaging 8s. a ton are now on hand, are stacked. About 50 tons of concentrates yielding about £8 10s. per ton of gold are collected each month.

Table showing the Yield of the Ingliston Consols Extended G.M.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Silver therefrom.
		tons.	oz.	oz.
1903 ..	Ingliston Consols Extended 475N	59·25	227·47	..
1904 ..	do. do.	480·00	2,112·51	·30
1905 ..	do. do.	593·00	1,257·90	..
1906 ..	do. do.	404·00	650·37	..
1907 ..	Ingliston Consols Extd. leases, 475N and 515N	730·50	2,122·01	..
1908 ..	Ingliston Consols Extd. leases 475N, 515N, 729N	917·00	1,676·01	..
1909 ..	do. do.	4,608·00	4,833·46	..
1910 ..	Ingliston Consols Extd. leases, 475N, 515N, 729N, 822N	11,869·00	7,115·68	..
1911 ..	do. do.	13,693·00	10,314·26	..
1912 ..	do. do.	13,892·00	8,335·27	..
1913 ..	do. do.	19,266·00	11,274·06	..
1914 ..	do. do.	21,647·00	10,781·08	..
	Total	**88,158·75**	**60,700·08**	**·30**

Fenian G.M. Syndicate.—This syndicate of 14 members holds the Fenian and Fenian Extended Leases.

The application by F. O. Osborne and T. Ryan for the Fenian Lease was received on July 20th, 1903, twelve days after the Roberts party's application for the Ingliston Consols Extended. During its early days, the lease is said to have been worked at a loss. According to one account, three shafts were sunk to 50 feet and connected by cross-cuts in which the ore was unpayable, but 10 feet more sinking opened out a payable body 30 feet wide. In October, 1908, a battery bought from the Champion Mine at Nannine was working. The plant now includes a Cornish boiler, which supplies the winder (till the middle of 1914, the entire plant was worked by a 120 h.p. compound tandem engine supplied from four Cornish boilers, there was also a steam-driven cross-compound air-compressor—all this plant is still in position), two pairs of Kynoch gas engines, a Hornsby and a 260 h.p. Crossley, the total h.p. available being about 600.* These engines, which are supplied from two Commonwealth producers, operate a 1,050 c.f. per minute air compressor, a 15 kilowatt dynamo for lighting purposes, the 15-head mill of 1,200lb. stamps

* The total h.p. is not required at present, and one or more of the engines and one producer are held in reserve.

and the cyanide plant. A three decker Merton Roaster, with a capacity of eight tons per day of raw concentrates, driven off the main shafting, now deals with concentrates from the Fenian and other mines.

An account of the treatment is given in Chapter II.

Table showing the Yield of the Fenian Gold Mine.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1904 ..	Fenian, 477N	132·00	396·74
1905 ..	Do.	509·75	2,360·39
1906 ..	Do.	778·00	2,914·51
1907 ..	Do.	1,858·00	4,192·57
1908 ..	Do.	3,516·00	6,265·25
1909 ..	Do.	2,038·00	2,159·76
	Fenian Leases 477N and 814N amalgamated	9,401·00	12,350·29
1910 ..	Do. do. do.	11,642·00	14,954·38
1911 ..	Do. do. do.	16,237·00	15,945·59
1912 ..	Do. do. do.	25,872·00	21,837·81
1913 ..	Do. do. do.	30,932·00	24,805·15
1914 ..	Do. do. do.	33,945·00	26,401·03
	Total	**136,860·75**	**134,583·47**

The Marmont and amalgamated leases, Marmont Extended and Mickey Doolan, are held by T. Ryan, who with four others, originally pegged the Marmont ground at the same time as the Fenian. The Marmont Extended was first leased to F. J. Smith and the Mickey Doolan to Caleb James.

Table showing the Yield of the Marmont Gold Mine.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1905 ..	Marmont, 533N	274·50	415·01
1906 ..	Do.	804·50	3,265·55
1907 ..	Do.	3,532·00	2,887·69
1908 ..	Do.	8,661·00	6,065·94
1909 ..	Do.	9,840·00	7,015·98
1910 ..	Do.	6,587·00	4,179·24
1911 ..	Do.	7,272·00	5,551·65
1912 ..	Do.	6,406·00	2,509·12
1913 ..	Do.	5,120·00	2,436·67
1914 ..	Do.	3,913·00	2,623·97
	Total	**52,410·00**	**36,950·82**

Table showing the Yield of the Marmont Extended and other Leases.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1907 ..	Marmont Extended, 580N	43·00	38·03
	Ingliston Consols South, 544N ..	20·50	24·49
1910 ..	Marmont Extended Leases 580N and 888N	152·00	129·61
1910 ..	Ingliston Consols South, 544N ..	15·00	18·60
	Total	**230·50**	**210·73**

Although it took a year longer to find the lode on the Marmont than on the Fenian, a 20-head mill, purchased from the Weld Range Hercules G.M. Co., was working early in 1907, being thus the second private battery in point of age on the Belt. This battery is now reduced to 10-head and is driven by steam from two Cornish boilers, which also supply the two winding engines. Two years ago a cyanide plant, now idle, was operating. On the Marmont Extended the winder and one Cornish boiler are still in position.

The Marmont battery is close to the old main shaft, an overhead tramway connecting it with the new shaft. Tailings are stacked, there being now about 9,000 tons in hand. These are said to be of considerable value, but no figures are available.

2. *Geology.* (a.) *Country.* (i.) *Porphyry.*—This is generally an albite-quartz porphyry (*see* Chapter VII., p. 220).

At the north and south ends it forms, so far as known, a continuous bar. In the Ingliston Consols Extd., the Fenian, and Marmont, its occurrences are disconnected, but comparison of the plan (Plate XVI.) with the diagrammatic section (Plate XIV.) shows that in these mines the rock occurs in peaks, which will unite at greater depths to form a continuous bar. (One small occurrence in the Marmont is indeed said to be quite isolated, and is compared by the miners to a fish.) On levels 7 and 8 of the Fenian, the porphyry is faulted by an auriferous cross vein.

On the Mickey Doolan, the relation of the dyke to the surrounding decomposed fuchsite rock is shown in one of the sections in Plate XIX.

(ii.) *"Greenstones."*—Certain distinct types can be recognised even in hand specimens but, owing to the varying degrees of alteration, the mapping of their boundaries on the accompanying plans is only approximately correct. To define them accurately would involve an enormous amount of detailed petrological work in order to decide finally the character of specimens which to the naked eye

appear to be intermediate between the types. However, the complicated relations between the rocks of peridotitic and doleritic

Fig. 55.

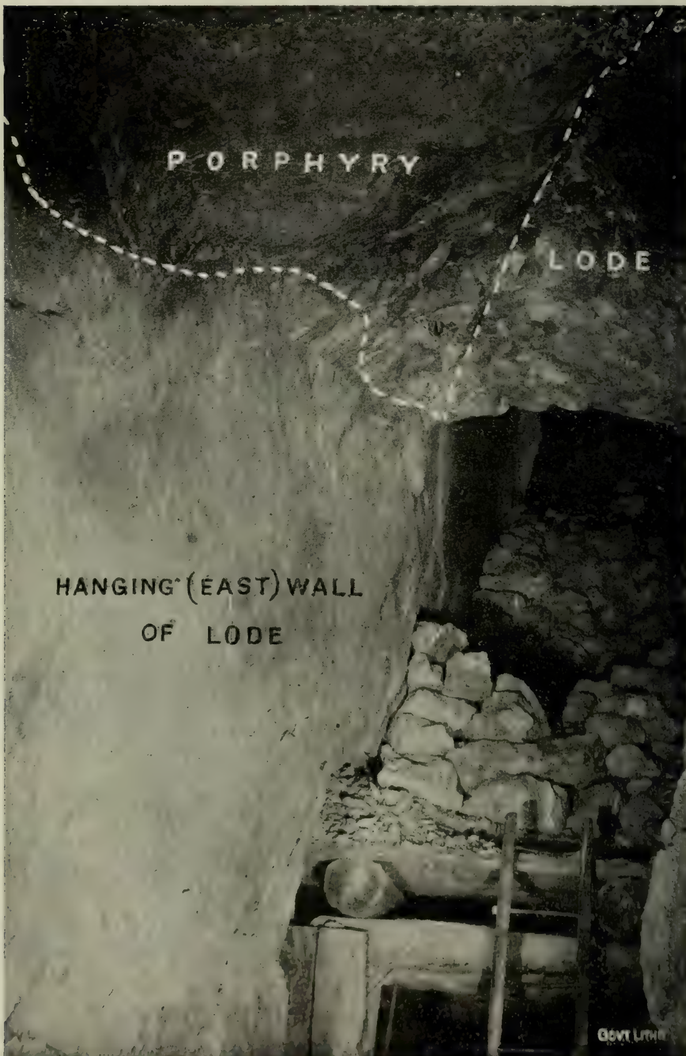


Photo.: E. de C. Clarke. Neg. 1416.

Porphyry and Lode, Ingliston Consols Extended G.M., looking south from north end of No. 4 Level. Porphyry wedges out below.

origin is quite in accord with field evidence near Garden Gully and Belele Homestead and an underground occurrence at Yaloginda, in which places peridotitic rocks are in close relation with others of undoubted doleritic character.

Flecked Carbonate Schists—originally dolerites.—It will be seen that these occur at the north end of the Group, but their boundaries are quite undefined.

Strictly the term schist applied to these or any other rocks in the Area is a misnomer since they everywhere show, both in hand specimens and under the microscope, evidence of their originally massive character. Generally they are greenish or grey-green, and owe their schist-like appearance to the numbers of shear-planes by which they are traversed and which generally strike parallel to the main lode channel and dip east. These rocks are usually flecked, owing to the presence of duller chloritic patches (*see* further, pp. 69, 258).

Fuchsite Rocks.—These rocks—also probably of doleritic origin, as indicated by microscope work—are found in various places in the Group—usually, but not always, alongside the porphyry, on to which they are generally "frozen" or "dovetailed." Occasionally, however, the two rocks are separated by a shear plane or are mixed together along their contact. All these relationships are also found in the Ingliston Extended Group.

The large area of fuchsite rock in the southern part of this Group is mapped solely by the character of the weathered product—a green, gritty, incoherent rock. Possibly some of this will prove at depth to be carbonate rock of peridotitic origin.

Carbonate Rock.—The bulk of the workings of the Group are in rocks of peridotitic origin, which in some places have been changed to crystalline carbonate rocks. In others by shearing they have much the appearance of the flecked schists, from which they can usually be distinguished even in hand specimens by less intensity of shearing and absence of flecked structure. It is, however, as already explained, usually impossible to draw definite boundaries between these two rocks.

(iii.) *Chief Determinations of Rocks from Consols Group.*

Specimen Number.	Locality.	Determination.
$[\frac{1}{87}]$	Ing. Con. Extd., No. 5 Level	Quartz porphyry with micacised felspar.
$[\frac{1}{88}]$	Fenian, No. 7 Level	Felspar porphyry.
$[\frac{1}{89}]$	Fenian, No. 8 Level	Felsitic quartz porphyry.
$[\frac{1}{90}]$	Fenian, Stope above No. 5 Level	do. do.

(iii.) *Chief Determinations of Rocks from Consols Group*—contd.

Specimen Number.	Locality.	Determination.
$[\frac{1}{96}]$	Marmont, 321ft. Level	Felsitic quartz porphyry.
$[\frac{1}{97}]$	Marmont, 196ft. Level	Fine-grained quartz porphyry.
$[\frac{1}{99}]$	Ing. Con. Extd., No. 4 Level	Probably porphyry.
$[\frac{1}{100}]$	Fenian, No. 7 Level	Banded carbonate-quartz rock.
$[\frac{1}{114}]$	Fenian, No. 8 Level	Fine-grained felsitic quartz porphyry.
$[\frac{1}{115}]$	Do. ..	Fine-grained quartz porphyry.
$[\frac{1}{183}]$	Fenian, No. 5 Level	Carbonated quartz-chlorite-talc rock.
$[\frac{1}{185}]$	Fenian, No. 7 Level	Carbonate chlorite rock (formerly platy plutonic).
$[\frac{1}{186}]$	Do. do.	Fine-grained fuchsite-quartz-carbonate rock.
$[\frac{1}{187}]$	Fenian, No. 6 Level	Talc-chlorite-carbonate-albite-quartz rock.
$[\frac{1}{188}]$	Marmont, 196ft. Level	? Quartzose porphyry.
$[\frac{1}{189}]$	Marmont, 321ft. Level	Talc-chlorite-carbonate rock.
$[\frac{1}{191}]$	Fenian, No. 9 Level	Chlorite-carbonate sheared flecked rock.
$[\frac{1}{192}]$	Fenian Main Shaft, V.D. 890ft.	Fuchsitic talc-chlorite-carbonate rock.
$[\frac{1}{193}]$	Fenian, No. 8 Level	Fuchsite-quartz-carbonate rock.
$[\frac{1}{209}]$*	Fenian, No. 5 Level	Cp. $\frac{1}{218}$.
$[\frac{1}{210}]$	Fenian, No. 2 Level	Talc-zoisite-chlorite-carbonate rock.
$[\frac{1}{212}]$	Fenian, No. 9 Level	Highly sheared chlorite-carbonate flecked rock.
$[\frac{1}{213}]$	Fenian, No. 6 Level	Sheared talc-chlorite-carbonate rock.
$[\frac{1}{214}]$	Do. do.	Slightly flecked talc-chlorite-carbonate rock.
$[\frac{1}{215}]$	Fenian, No. 3 Level	Talc-chlorite-carbonate sheared flecked rock.
$[\frac{1}{216}]$	Fenian, No. 8 Level	Strongly sheared talcose chloritic rock.
$[\frac{1}{217}]$	Do. do.	Sheared talc-chlorite-carbonate rock.
$[\frac{1}{218}]$	Fenian, No. 7 Level	do. do. do.
[1d]	Marmont, 145ft. Level	
(2d)	Do. do.	Talc-chlorite rocks.
(3d)	Do. do.	
(4d)*	Do. do.	
(18d)	Fenian, No. 9 Level	Porphyry.
(19d)	Do. do.	Porphyry; felspar largely altered to muscovite.
(66d)	Ing. Con. Ext., bottom of shaft	Sheared porphyritic fine-grained dolerite.

* $[\frac{1}{209}]$ to (4d) are of peridotitic origin.

(iv.) *Fissures.*—Two systems of fissures—a main and a subsidiary—are recognised. The former, striking about 20° E. of N., runs parallel to the shear-planes of the country, and along it are deposited the main ore-bodies of the group; the latter is roughly at

right angles to the main system and, in the Fenian and Marmont "spur-veins," also carries valuable ore-deposits.

In the Ingliston Consols the cross-fissures are in places very numerous, but small. In some parts of the mine they run into, but do not cross, the main system.

In the Fenian, the cross-fissures are larger and more important economically.

The cross-fissure along which the Marmont "No. 2 spur" lies is the largest and, in some ways, most important in the Belt. Owing to its size it diverted the ascending solutions from the main lode-channel, and, with the Fenian South-East Spur, is responsible for the poorness of the south part of the main channel in the Fenian ground.

At first sight, the subsidiary system, since it faults the main lode channel, throwing it west as we go north, would seem to be decidedly later than the main system of fissures. The writer thinks, however, that both systems were formed almost simultaneously, although in one or two instances slight transverse movement occurred a little later. It cannot be supposed that such widespread systems of longitudinal and cross-fissuring and shearing as exist throughout the Area were formed everywhere at the same time. Along lines of weakness there is usually repeated movement at different ages. It would be as much a mistake to regard all transverse fissures as of one age and all later than the longitudinal, as it would be to suppose that all the longitudinal fissures and shear-planes are themselves coeval.

(b) *Ore-deposits.*—The main ore-channel is a mineralised shear-zone striking N.N.E. and dipping east, which had been, just before the arrival of the gold-solutions, the path followed in places by an invasion of porphyry.

The main lode consists generally of quartz veins of all sizes in a matrix of sheared rock much impregnated with arsenopyrite.*

In hand-specimens, the quartz of this lode, which is generally milky-white and contains no visible minerals except gold, is in many places traversed by minute branching "capillaries" of clear quartz. Microscopic examination of similar quartz from the Gwalia Extended Lease shows that the "capillaries" are in crystallographic continuity with the quartz forming the rest of the vein, but are quite without the liquid inclusions with which the main mass is thickly dusted, and for this reason stand out distinctly.

The gold not actually contained in quartz veins and stringers but carried by mineralised country, is "face gold," being confined to the shear-faces and not distributed through the mass of the rock.

* For mineral content *see* Chapter VIII.

Pyrite is thought a bad "indication"; however, in a specimen from No. 5 level, Ingliston Consols, visible gold is associated with good pyritohedra.

Fig. 56.

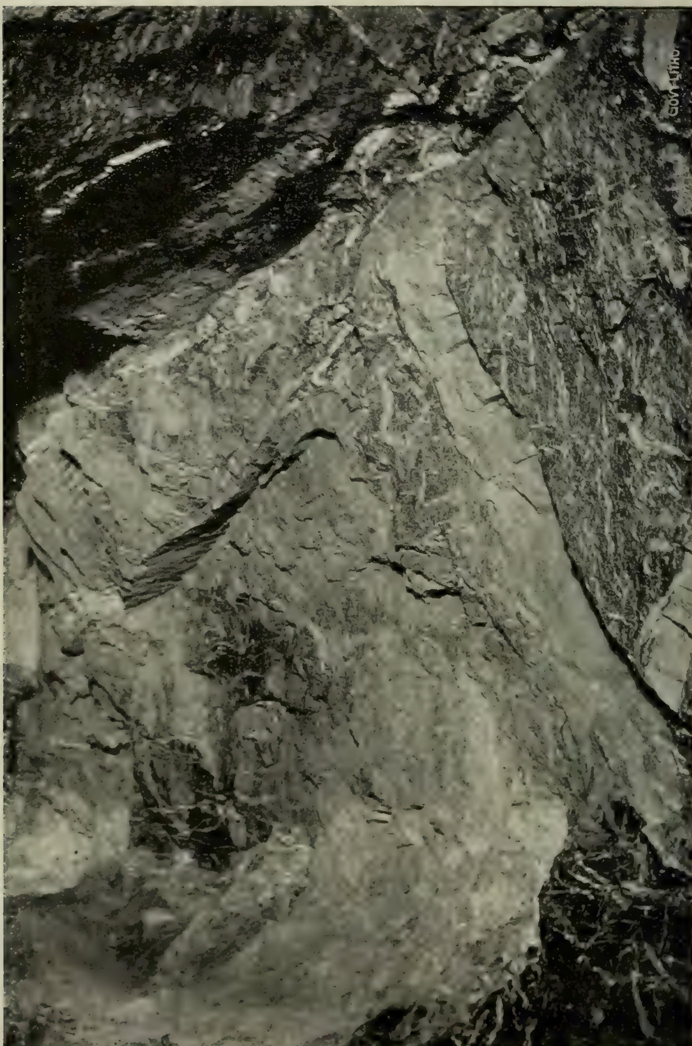


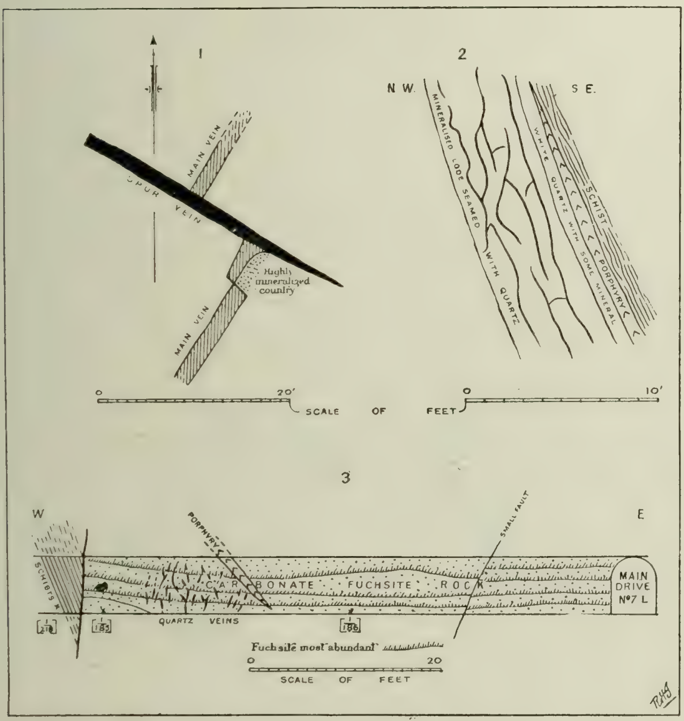
Photo.: E. de C. Clarke. Neg. 1415.

Lode, Fenian G.M. Roof of drive, No. 8 level, near north end. One quartz vein cuts another. The schist is netted with quartz veinlets.

Where the porphyry dyke occupies the channel, the lode can generally be found along one or both sides (Figs. 19 and 55), but is neither so rich nor so large as where the porphyry is absent (*see* stope-section of the group, Pl. XIV., in which the approximate projection of the dyke is shown in colour).

As in the Commodore and Ingliston Extended Groups, where peridotitic or fuchsite rocks are intersected by the channel the ore is more patchy than when in the "flecked schists."

Fig. 57.

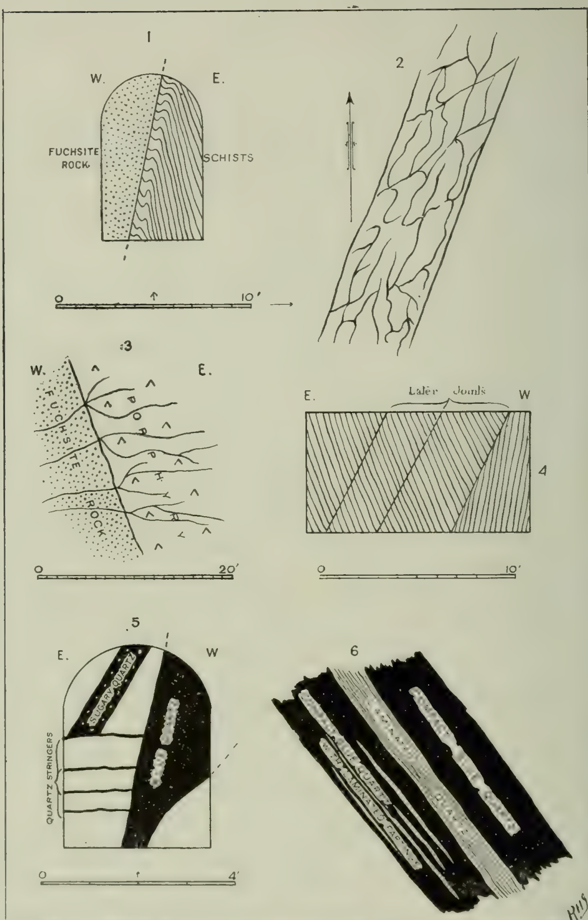


Fenian G.M. Diagrams showing some geological features.

1. No. 7 level, 200ft. north of main cross-cut—relation between main vein and a spur (plan).
2. No. 6 level—Relation between lode, porphyry, and schist (section).
3. No. 7 level—Section along north side of main cross-cut.

The gold solutions apparently came from the same magma as the porphyry and were circulating through the ore-channel before the acid rock had completely solidified. Thus auriferous quartz

Fig. 58.



Geological Features in Workings near Meekatharra.

1. Ingliston Consols Extd. G.M., 174ft. level (section).
2. Ingliston Consols Extd. G.M.—Arrangement of quartz veinlets in lode (diagrammatic plan).
3. Marmont G.M., 196ft. level—Quartz veins are auriferous at contact of fuchsite rock and porphyry (section).
4. Ingliston Extd. G.M., 300ft. level—Shear planes of schists displaced by later joints (section).
5. Pioneer Group, Shaft 7—A "sugary" quartz vein cut off by stringers from main vein (section).
6. Pioneer Group, Shaft 11—Section showing structure of vein. Scale: 4ft. = 1in.

veins are occasionally (south end of no. 5 level Ingliston Consols) found cutting the porphyry. It is even said that gold is found in the porphyry itself, but in the few instances seen by the writer, the gold was in small quartz stringers, which had penetrated the rock.

In the Ingliston Consols the main lode-channel carries very numerous (usually small) quartz veins in which two directions of orientation are said to be recognised (Fig. 58, no. 2). The complicated character of the earlier workings is due to the fact that only the rich quartz veins were then mined. The cross-fissures in this mine are numerous and appear, particularly in the stopes above No. 4 level, to have thrown the lode west (going north) in a succession of steps. This is a case in which the transverse fissures are later than the longitudinal. Elsewhere in the Ingliston Consols the cross-fissures, which strike and dip steeply in various directions, generally carry higher grade quartz than the main body, but only persist for a very short distance outside it.

The ore-body in the Fenian G.M. is narrower, contains a higher proportion of quartz, and is complicated by the greater size and importance than in the Ingliston Consols of the cross- (or spur-) veins. The general course and size of the spurs is indicated on the plan (Pl. XVI.), but no idea of their contribution to the ore produced by the mine is given by the stope-section (Pl. XIV.) which, being taken parallel to the main channel, shows the stoping on the spurs greatly foreshortened.

The writer considers that the comparative failure of the ore-body in the south part of the mine is due to diversion of ascending solutions by the fissures of the S.E. spur and No. 2 Marmont spur, which have thus robbed the main channel.

In the Marmont the ore-body is like that of the Fenian, "spurs" being of considerable importance. A characteristic of No. 2 spur, which differs from others in that it carries a lode-formation of schist in addition to much quartz, is said to be the presence of small more or less horizontal quartz partings which separate the body into high- and low-grade segments.

There is little information regarding the ore-deposits of this group south of the Marmont. This part has not been adequately prospected, and, except in the main workings of the Marmont Extended, the position of the ore-channel has not been located.

3. *Future prospecting.*—The description of the Ingliston Extended Group shows that in the extreme north of the Consols Group the dolerite intrusion, the large porphyry dyke, and the character of the country are alike unfavourable to the existence of a large ore-body.

Until the Ingliston Extended East Lode has been located in the south part of that group (*see* above, p. 149), it is little use speculating as to its possible extension along the east side of the Consols Group. It would appear from the different character of its ore to be a body distinct from the Consols lode, of which the Ingliston Extended West Lode is probably the continuation, and to this extent there is reason to hope that it will yet be found to the east.

As regards the position of the ore-channel in the south part of the Consols Group, two possible courses between the Marmont Extended and Gwalia Extended leases are indicated (Pl. XIII., sheet 8). Early records of the Fenian, together with recent developments on the Gwalia Extended (*see* p. 165), indicate that, going south, the true character of the ore-body cannot be gauged until a depth of at least 150 feet has been reached.

E. Gwalia Extended Group (Pl. XIII., sheets 8 and 9).

1. *History, etc.*—The workings of this group are in the Gwalia Extended (872N), Fenian South (1019N), and Judy (925N) leases.

The Gwalia Extended was taken up by J. Eves and party in 1909, the Fenian South by W. J. Weekly in 1910, and the Judy by D. Morris in 1909. The ground has since been cut up into other leases held by various parties.

The gold yield has been small, but a good deal of geological information may be obtained from the rather extensive series of cross-cuts.

2. *Geology.* (a) *Country.* (i.) *Peridotitic Rocks—Black Carbonate Rock.* This locality shows the difficulty of determining the origin of the highly metamorphosed rocks of the Area. Judging by hand-specimens, $\left[\frac{1}{202}\right]$ and $\left[\frac{1}{205}\right]$, from this group (like $\left[\frac{1}{201}\right]$ from the New Orleans) might well be highly sheared representatives of the andesitic tuffs and breccias which occur near by at the surface (*see* p. 65). The microscopic structure of $\left[\frac{1}{202}\right]$ and $\left[\frac{1}{205}\right]$ and the rocks into which they quickly pass both along and across their strike, show that they are peridotitic in origin and are best classed with the black schists of the Ingliston Extended G.M.

(ii.) *Fuchsite Rocks.*—From F Shaft to the porphyry (a distance of 350 feet), and again west of the porphyry, the country is the green gritty product, in places containing bands of limonite, which in other parts of the Belt is found to pass at depth into fuchsite rock.

(iii.) *Porphyry.* In the north part of the group the dyke, though highly decomposed, can be defined. To the south (shafts

J, K, and L) there is little doubt, judging from the characteristic alteration of the country, that the porphyry is very close, and its approximate position is indicated.

The porphyry usually carries many quartz veins, the flatter being apparently the younger (section in Pl. XIX.). The latter at the 93ft. and 125ft. levels (shaft H) carry nests of tourmaline—the tourmaline being so abundant that it sometimes seems to lie in the decomposed porphyry without any enclosing quartz.

The contact between fuchsite rock and porphyry varies in character from place to place. There is in the small section in Pl. XIX. evidence of slight movement along the west porphyry wall after the formation of the youngest veins.

(b) *Lodes.*—In quartz stringers in the fuchsite rock close to its contact with the black schists values have lately been obtained in shafts F and F1. The stringers dip west at low angles and, where they join, an inch seam of rich quartz is said to occur (Fig. 52). In the 50ft. cross-cut (shaft F) values were almost absent, in the 112ft. cross-cut they are said to have been about 4dwt. per ton, but to have improved in the winze. Forty-five tons from the 94ft. level (shaft F) are said to have averaged 8dwt. 4gr. in all.

If these figures are correct, deeper prospecting in this part of the Belt is advisable.

Another "lode" (so called from the abundance of quartz stringers, not the values, which it contains) lies about 70 feet further west.

It is assumed that the irregular stringers followed in shafts M and N, and the other system, apparently no more productive, in J and K, are the same two lodes. Their probable course between the two sets of workings is indicated to guide further prospecting.

The flat veins issuing from the porphyry (shaft H, *see* Fig. 52) are said to be auriferous both in the porphyry and for a short distance in the fuchsite rock.

IX. GLOBE GOLD MINE. (Pl. XVII.)

1. *History, etc.* Reef-gold was first obtained in this neighbourhood (about two miles south of the Marmont G.M.), in 1908, from shaft A.

In August, 1909, a small rush resulted from the finding of rich "floaters" on the present Globe lease by G. Wilson and G. Gibson, and about 200 acres were pegged. Work was done only on the Globe, Globe Extended, and Shipmate leases. On the last-named, Weekly and Son were reported to have opened up a small vein yielding 5 oz. assays. The Globe G.M.L., after being twice under option, passed into the hands of a syndicate which, in 1912, sank

the main shaft, equipping it with steam-winder and angle-iron poppett legs, and did most of the mining shown on the plan. At the lower level water was at first heavy, but soon eased to 200 gallons per hour.

In March, 1914, it was proposed, but apparently the proposal was not warmly supported, to provide more capital for the development of the mine by forming a local company.

Table showing the Yield of the Globe Gold Mine.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1910 ..	Globe, 912N	55·00	32·77
1911 ..	Do.	307·35	492·84
1912 ..	Do.	393·13	634·64
1913 ..	Do.	37·50	23·30
	Total	**792·98**	**1,183·55**

2. *Geology.*—The following remarks do not apply to the neighbourhood of shafts A and B, which are in jasper bar country (*see* below, page 173).

All workings except the main ones, and possibly shafts 10 and 11 and potholes Q and R, are in sheared rocks of the black schist type (*see* above, page 71), which occasionally carry small (and apparently barren) quartz stringers.

The ore of the main workings has come from quartz veins, some dipping steeply, others almost flat, contained in carbonate-fuchsite rock, the approximate limits of which are indicated on the plan. Although this rock is usually accompanied by porphyry, no sign of the latter was found in any of the Globe workings.

The workings at the north end of the mine, down to the 108ft. level, are on an east-dipping quartz vein and its branches. This vein is usually called the "northern ore-body" and was the first found. The later, more extensive, south workings are on a west-dipping vein and its branches (the "southern ore body").

The northern body was at its best between the 25ft. and 54ft. levels, where it was occasionally 1ft. 6in. wide, but was liable to break up into mere threads of quartz. At 70ft. it became flat and died out.

The southern ore-body is probably a west-dipping vein crossed by small west-dipping faults along which the values are higher than in the main fissure. This structure recalls the ore-occurrences of parts of the Commodore and Ingliston Mines. The small rich

veins worked at the 67ft., 98ft., and 210ft. levels, and the flat parts of the stope above the 120ft. level, which are really on branches, and not on the main body (Fig. 52), are examples of the importance of spurs in this mine. At the 98ft. level several flat heads have yielded gold. One carried no quartz but yielded crystalline gold which could be brushed into a dish when a fresh section of the head had been exposed.

The relation of the flat spur at the 210ft. level to the other veins and fissures in the fuchsite rock is illustrated in Fig. 52. Probably the "secondary head" is the earliest feature; next came the barren veins. The auriferous vein and "main head" were contemporaneous, but there is no evidence as to the relative age of the arsenopyrite impregnation.

X.—QUEEN OF THE HILL LODE AND SIMILAR DEPOSITS.

(Plate XIII., Sheets 3, 5, and 7.)

1. *History, etc.*—Very soon after the discovery of the Paddy's Flat Lode, the neighbourhood of the Queen of the Hill Lease, where fine colours could always be obtained by panning, attracted attention. Owing, however, to the thickness of the "cement" few serious attempts were made to find the parent ore-body.

The "Tidal Wave" (411N), held for a few months in 1901 and 1902 by W. C. Smith and others, who obtained 6.04 ozs. from 20.75 tons of ore, was the first real prospecting effort in this neighbourhood.*

In October, 1909, W. Hazzard applied for the "Queen of the Hill' (931N), which covered ground formerly held as prospecting areas by C. M. Roberts, G. M. Little and others. A shaft was sunk to 80 feet and apparently some payable ore was found. In December, 1910, after 10 months' option, the lease was purchased by the Oroya Exploration Co., Ltd. Nearly two years were spent in further development, after which the plant was erected, and crushing began in February, 1913. With the Queen of the Hill lease, on which most of the Company's work has been done, are amalgamated 507N, 637N, 933N, 964N, 1071N, and 1142N. Notes on some of these leases have been given under the Ingliston Extended Group, the others are unimportant.

The Oroya Exploration Co. at different times held options over the Queen of the Hills East (1142N), Remnant (976N), Bobs (961N) and Bobs Extended (960N) leases, and prospected in a small way and without success for the continuation of the Queen of the Hill Lode.

* This lease (unsurveyed) was on the ground now covered by 996N.

Table showing the Yield of the Queen of the Hill Lodes.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Silver therefrom.
		tons.	oz.	oz.
1909 ..	Queen of the Hill, 931N	130·00	34·69	..
1910 ..	do. do.	419·00	123·90	..
1913 ..	Lake View and Oroya Exploration, Ltd., Amalgamated leases 507N, 637N, 931N, 933N, 964N, 1071N, 1142N (all ore from 931N)	34,989·00	14,469·39	601·57
1914 ..	do. do.	41,393·42	16,048·13	637·05
	Total	**76,931·42**	**30,676·11**	**1,238·62**

There has been prospecting in jasper bar country like that of the "Queen" at intervals as far south as the Globe G.M. Mention may be made of:—

The *Fenian West* (1199N) and *Golden Bar* (962N). These have been held occasionally, the former since 1904, the latter since 1907. On the latter, shaft 3, with 300 feet of cross-cutting, is the only work of note. The return of 6.69 ozs. from 24.74 tons in 1911 from "Golden Bar Leases" probably came from Fenian West ground. The Fenian West was amalgamated with the Golden Bar in 1910, and some work was also done on it in 1913-14 by a syndicate.

On the *Gold Queen* (1246N), which included parts of 985N, 868N and 995N, from which, in 1913, 17 tons of ore produced 2.07 fine ounces of gold, are a few small workings in jasper bar country.

2. *Equipment of Queen of Hill G.M.*—One Lancashire and two Cornish boilers supply steam to winder, air-compressor (which drives rock drills, auxiliary pump, Holman hoist, etc), vertical Cameron sinking pump, fitting shop and sample-mill engine. The gas engine, a 220 b.h.p. tandem cylinder Kynoch, supplied from a 250 h.p. Commonwealth wood-producer, drives the treatment plant (*see* Chapter II., p. 34), a dynamo, and refrigerating plant of 10 cwt. capacity.

3. *Geology*—(a) *Country;* (i.) *"Greenstones."*—The greenstones of the Queen of the Hill G.M. are all of doleritic origin. As the plan shows, nearly all the country is of the chloritic slate type already mentioned in dealing with the Commodore G.M. In the weathered zone, this rock is sometimes completely bleached and the shearing obscured. In this form it has sometimes been mistaken for kaolinised porphyry.

The flecked schists are mainly developed in the south-eastern part of the mine. $\left[\frac{1}{197}\right]$, from No. 3 level, is regarded as the type specimen of the flecked schists (*see* Chapter VII).

The strike and dip of the greenstones are very variable owing to the earth-movements which formed the lode-channel.

(ii) *Jasper Bar.* The ore-deposits in the "Queen" and lesser workings enumerated above are closely associated with the jasper bars, of which a general description is given in Chapter IV., p. 82. From the general geological map of the Area, it will be seen that all the workings are probably on one Jasper Bar, and that this shows an easterly twist at its north end. The bar is generally regarded as east-dipping in the Queen of the Hill, but evidence for this is scanty.

(b) *Ore-deposits.* (i) *Queen of the Hill Lodes.* These are all situated where faults striking about north and south cut obliquely through, and to some extent dislocate, the jasper bar. The structure and chemical composition of the bar have caused the deposition of gold in it near the fissures. Where these fissures traverse ordinary country such deposition has not taken place.

The plan of the Belt shows that these fissures are probably spurs from the main lode-channel of Paddy's Flat. The chloritic slates are proved in the Commodore G.M. to be unfavourable for ore-deposits, but in those places where they have been converted into jasper bar material, as in the Queen of the Hill, they become favourable.

Three lines of lode, associated with fissuring of the jasper bar, are recognised in the "Queen":—

The Main Ore-channel lies along a west-dipping thrust-zone by which the jasper bar has been dislocated. This zone is bounded by two planes, which are found at distances from one another varying from a few inches to 30 or 40 feet, and are generally called the eastern and western fault planes. The same thrust-zone can be seen to the north in shaft VI. and to the south in the Consols North shaft. It was the finding of the zone in the latter place, in 1911, which led to the report that the Ingliston Consols lode had been cut.

The jasper bar has been dislocated along the Main Ore-channel and, since the jasper is apparently a precipitant of gold-bearing solutions, ore-deposits known respectively as the northern and main bodies have been formed against both dislocated ends of the jasper bar. The amount of dislocation lessens with depth, and the ends have not slipped quite past one another, so that the two ore-bodies are continuous at the lower levels.

It appears that, while the main part of the jasper bar is pinching out at depth, the northern dislocated part is enlarging. With increasing depth, the upper level conditions may therefore be expected to reverse, and the northern body, which is small near the surface, to become large while the main body decreases; *i.e.*, the future development of the mine will be to the north.

Ore-deposits along the Main Channel were, almost to the surface (*see* Fig. 59), limited by the eastern and western fault-planes,

Fig. 59.

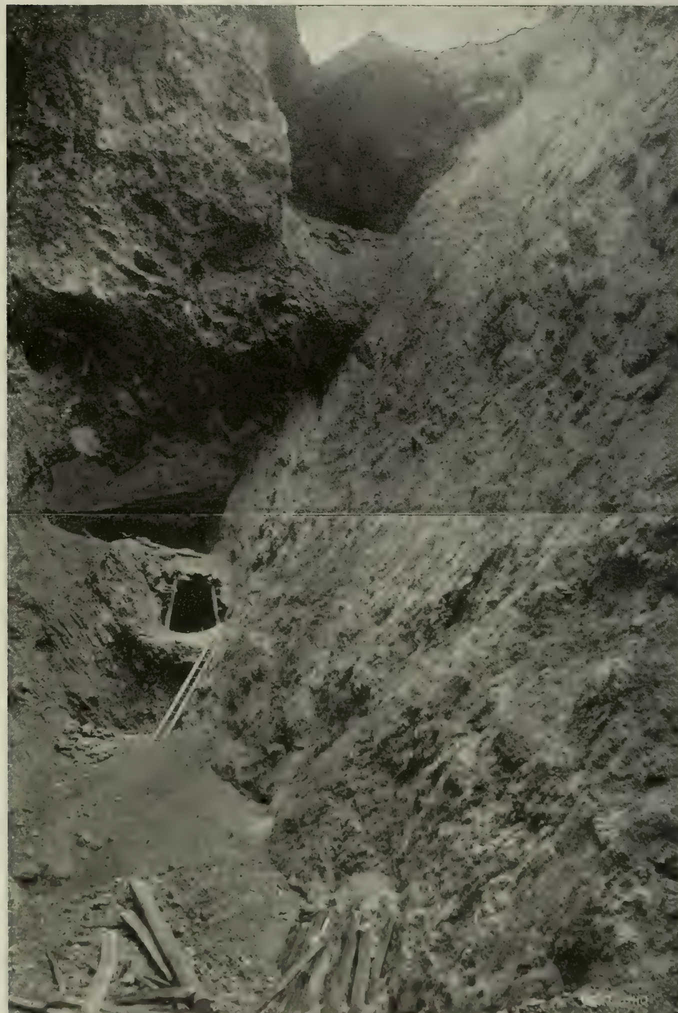


Photo.: E. de C. Clarke. Negs. 1422-3.

Open Cut, Queen of the Hill G.M., looking north. East side of open cut is both east fault-plane and foot-wall of lode. Contorted jasper lode shows to left of drive, which is north part of 80ft. level.

and there was no "spread enrichment" * in the zone of oxidation, nor is there reason to expect any permanent narrowing of the area within which gold has been deposited, below this zone.

Fig. 60.

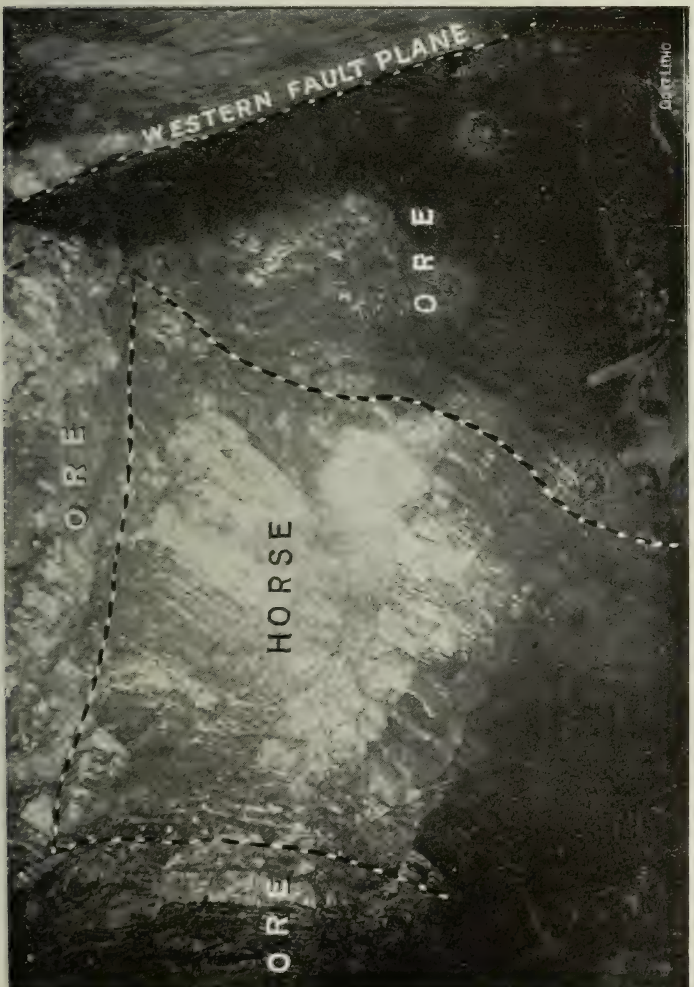


Photo.: E. Klug.

Western Fault-plane and ''Intrusion,'' Queen of the Hill G.M., Stope (V.D. 125ft.) at 215ft. north.

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* As distinct from secondary enrichment which did occur.

The main channel is crossed above the No. 2 level by some rather flat, east-dipping faults which have caused "intrusions" of non-auriferous jasper into the channel (*see* Figs. 60 and 61, also sec-

Fig. 61.

Photo.: E. Klug.

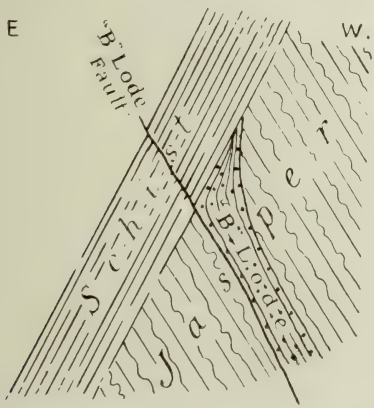
"Intrusion" in Jasper Lode, Queen of the Hill G.M., No. 2 Level, at 400ft. north.
"Intrusion" appears to pitch north and dip west at low angle.

tion in Plate XIX.). In the lower levels "cross-courses" (vertical joint-planes, apparently) strike across the lode. On one side of these the ore generally shows enrichment, and on the other, impoverishment.

The "A" lode has been most extensively worked as a separate body at the No. 2 level. It lies west of the main ore-channel, borders on a fault-plane, which dips west at about 45° and joins the main ore-body at the south end of the open-cut.

The "B" lode is east of the Main Ore-channel and, like "A" lode, borders on a west-dipping fault, which does not lie entirely within the jasper and, on reaching the "hanging-wall" of the latter, loses values, as shown in Fig. 62.*

Fig. 62.



Sketch showing limitation of ore in "B" Lode, Queen of the Hill G.M., to that part of fault which is in jasper bar (by L. B. Williams).

(ii) *Other Deposits of the Queen of the Hill type.—Fenian West.* The jasper bar yields low values along a west-dipping fault which strikes almost parallel instead of obliquely to the course of the bar. This fault is itself faulted by planes which dip east at rather low angles (Fig. 63) and are similar to the faults causing the "intrusions" in the "Queen" lode.

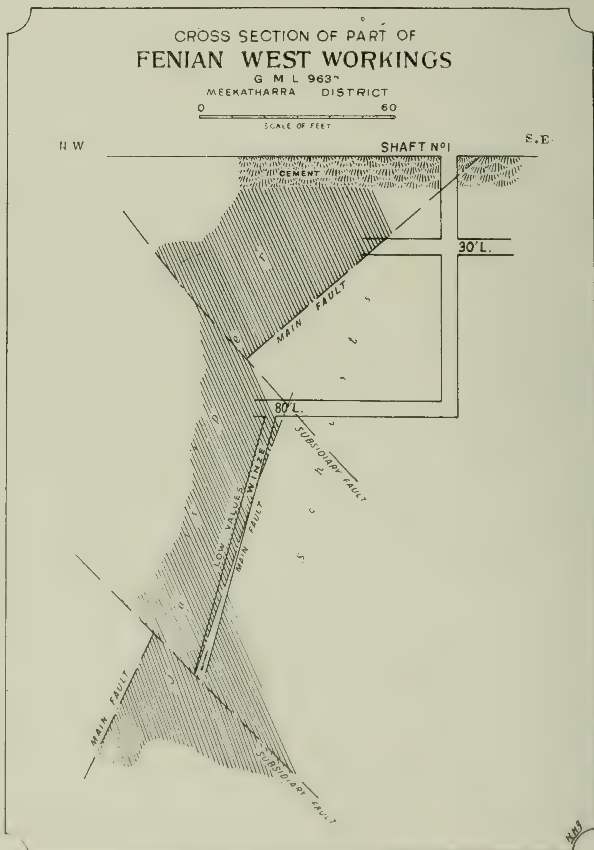
Globe G.M. Shaft "A" has already been mentioned. The workings are on an irregular vertical vein about 2ft. wide which strikes in a north-west direction into the jasper bar. Values appear to have been confined to the south-west wall of the vein. Shaft "B" shows merely a section through jasper bar material.

* For which the writer is indebted to Mr. L. B. Williams.

The workings on the Eldorado (935N) and other leases mentioned in the historical section throw some light on the general geology in their vicinity, but have disclosed nothing of economic value.

4. *Future Prospecting.* Important gold deposits of the Queen of the Hill type can only be expected where a jasper bar is crossed

Fig. 63.



obliquely by a strong fissure. Since the main ore-channel and jasper bars are parallel, except where the latter have their easterly twist, it appears unlikely that any other deposit of this type will be found.

Deposits remunerative to small parties may occur wherever the jasper bars appear to be faulted. An examination of the geological

map of the Area will show a few such apparent dislocations. Some attention might also be given to the locality mapped in detail by Mr. A. Gibb Maitland (Fig. 34).

XI.—WORKINGS NORTH OF YALOGINDA BELT.

A.—"Stockholm G.M." (Fig. 64).

1. *History, etc.* The abandoned workings known by this name are situated near Meekatharra Creek, about three miles south-west of Meekatharra. They were worked during 1912, when a lease of the above name was applied for but abandoned before survey.

Table showing the Yield of the Stockholm Gold Mine.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1912 ..	Stockholm (lease not surveyed), 1188N	9·94	19·17
1913 ..	Stockholm (lease not surveyed), 1188N (alluvial)	..	1·88
	Do. do. do.	86·26	71·73
	Total	96·20	92 78

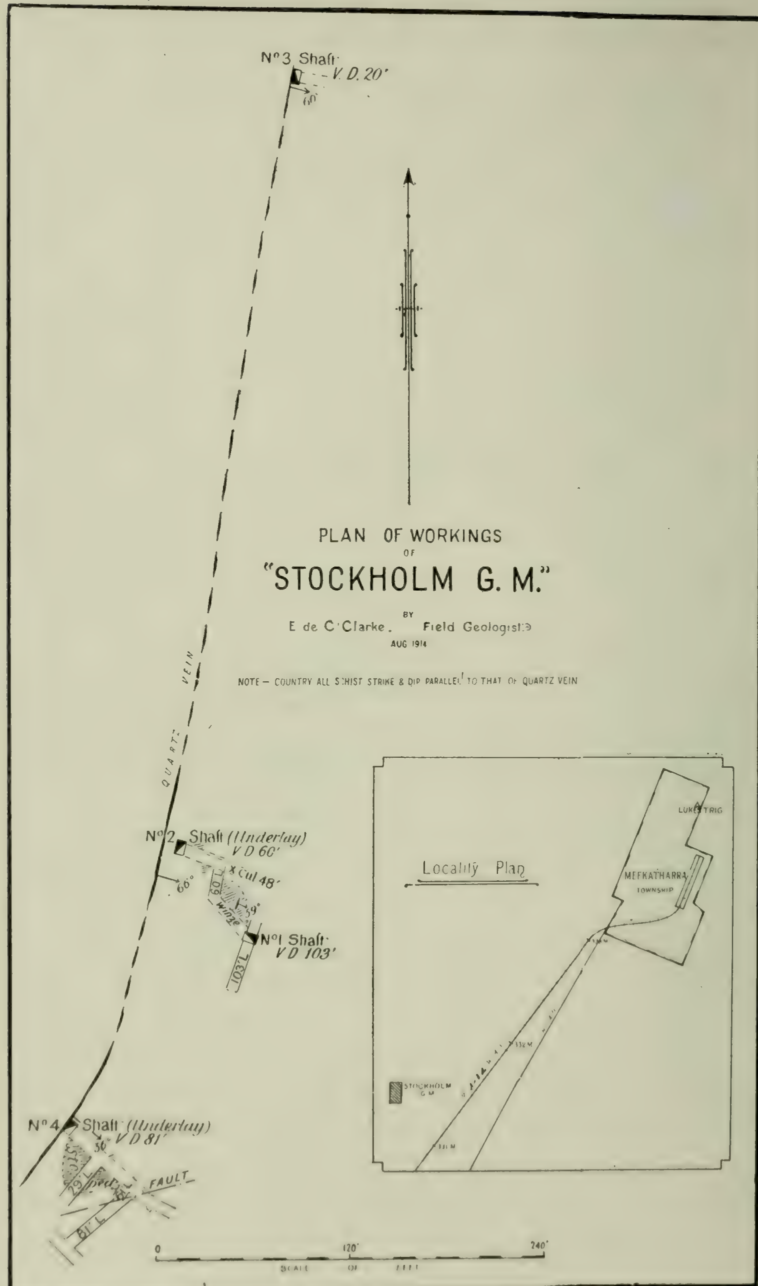
2. *Geology.* (a) *Country.* Down to the 100ft. level the rocks are greatly decomposed schists, usually stained light green, which strike N.E. and dip S.E. at about 60°. The outcrop of acid intrusive (Plate IV., sheet B) a little east of the Stockholm, probably extends nearer the workings, for light green colouring of the schists generally indicates in the Area the proximity of a porphyry dyke.

(b) *Vein.* The vein of pale yellow vughy quartz, which runs parallel to the shearing, never exceeds a foot in thickness and dwindles to a few stringers in shafts 4 and 1. In the southern workings the value of the quartz is said to have been determined by a "graphite indicator," which continued on its course when the vein cut out. Values, always obtainable when the indicator ran in the vein or in the hanging-wall, are said to have disappeared when it passed to the footwall.

According to report 48 tons from shaft 4 averaged nearly 1¼ oz., but the vein was cut off by a "disturbance," south of which nothing was found. 28 tons, going a little over the ounce, came from shaft 2. It is said also that 2oz. values were obtained in shaft 3.

About one mile W.S.W. of the Stockholm a shaft has been sunk 24 feet on a "formation" of glassy vughy quartz and limonite, which dips N.E. at 60°. "Specimen stone" is said to have been obtained in sinking this shaft.

Fig. 64.



PLAN OF WORKINGS
OF
"STOCKHOLM G. M."
BY
E de C Clarke. Field Geologist.
AUG 1914
NOTE — COUNTRY ALL SCHIST STRIKE & DIP PARALLEL TO THAT OF QUARTZ VEIN
N°3 Shaft
V. D. 20'
QUARTZ VEIN
N°2 Shaft (Underlay)
V D 60'
66°
Cut 48'
N°1 Shaft
V D 103'
103' L
N°4 Shaft (Underlay)
V D 81'
FAULT
29' L
81' L
Locality Plan
LUKE'S TRIG
MEEKATHARRA
TOWNSHIP
STOCKHOLM G M
0
120'
240'
SCALE OF FEET

3. *Future Prospecting.*—The porphyry dyke thought to exist near the Stockholm is a hopeful sign, and the surrounding country deserves careful prospecting for small rich quartz veins of the Yaloginda type.

B. Sirdar Group (Plate XX.).

1. *History, etc.* The Sirdar Group lies three-quarters of a mile west of the 329 railway mile-post. The Sirdar (246N) was applied for in January, 1899, by E. Dickson and R. Richards, and was thus the first ground prospected near Yaloginda. The Sirdar North and Blue Danube were taken up a few months later and held for a short time. The Sirdar was forfeited in 1905, but held again (as the Criterion) from 1907 to 1912. The Blue Danube ground was held again under the names of Calliope and Rajah between 1902 and 1905.

Table showing the Yield of the Sirdar Group.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1899 ..	Sirdar, 246N	38·00	48·99
		..	*12·71
1899 ..	Blue Danube, 252N	77·50	168·89
1900 ..	Sirdar, 246N	..	*37·21
1901 ..	Do.	80·25	46·53
		..	*4·90
1903 ..	Do.	28·75	26·81
1903 ..	Calliope, 450N (former 252N) ..	26·50	13·38
1904 ..	Sirdar, 246N	43·25	21·04
1904 ..	Rajah, 560N (former 450N)	41·00	7·20
1908 ..	Criterion, 760N (former 246N) ..	72·50	43·71
1909 ..	Do. do. do. ..	312·50	224·59
1910 ..	Do. do. do. ..	127·00	67·64
1911 ..	Do. do. do. ..	115·11	65·04
1912 ..	Do. do. do. ..	12·36	7·96
	Total	**974·72**	**796·60**

* Dollied and specimens.

2. *Geology*—(a) *Country.*—The superficial deposits in this neighbourhood are fully 10ft. thick. Underground the country is soft, sheared and much decomposed, usually carries quartz-partings, strikes N.N.E. and dips east at about 65°. Its minute structure (much obscured by weathering $\left[\frac{1}{341-2}\right]$) resembles that of the fine-grained epidote-zoisite amphibolite $\left[\frac{1}{302}\right]$ from the Old Battery Group, but the rock has been mapped as part of the sheared amphibolite belt of Yaloginda. At the south end of the group, a patch of the highly decomposed, supposed massive amphibolite noted above (page 68) occurs.

(b) *Veins.*—The "Buck Reef" (in 71ft. level off shaft 9) is a mass of veins of mottled blue and white quartz amongst which is some kaolin showing mica flakes. It is thus probably a phase of the Yaloginda porphyry dyke which outcrops nearby. The Buck Reef, it is said, yields good prospects where the quartz is ironstained and obliquely jointed. This large body certainly deserves more trial and exploration.

All the other veins are of glassy vughy quartz, seldom more than a foot thick, parallel in strike and dip to the enclosing schists and, like most of the Yaloginda veins, are of the "kidney" type. Thus none of them can be traced far either vertically or horizontally. Bordering the Sirdar veins, a fibrous decomposed mineral, probably hornblende, is frequently found.

There is evidence of the junction of two vein-systems both in the Blue Danube and in the Sirdar Leases. It was probably the junction of the West Vein with the Buck Reef that formed the rich shoot near shaft 9. With this exception the gold-output of the group has come from the system of veins which runs parallel to the strike and dip of the schists. Traces, at least, of gold are also obtainable, it is said, everywhere in the vein running thus in the Blue Danube Lease.

A little work in some small shafts about a quarter of a mile to the S.S.E. has been done on the southern continuation of the Sirdar veins. No particulars are available.

Half a mile south of the Sirdar Group (*see* inset to Plate XX.) a few shallow shafts and more than 300 feet of cross-cutting lie in a highly decomposed "massive amphibolite" of the type already mentioned. No particulars can be got regarding these workings.

XII.—YALOGINDA BELT.

A strip of country, extending about one and a half miles north and south of Yaloginda Townsite and about a mile wide, is dotted with small abandoned workings, of which the chief lie on two low hills carrying many jasper bars (Fig. 65). Geologically, this strip is uniform, and should be discussed as a unit. For convenience in printing of maps, it has been divided into a larger northern part—the Yaloginda Belt—and a southern part—the Black Jack Group. Names have in this report been given to the different vein-lines, although their continuity for the distances mapped has not been proved. In localities without workings where the vein-lines are indicated, future prospecting is warranted.

Records show that the veins of the Yaloginda Belt and Black Jack Group have produced 9,489.81 fine ounces of gold from 3,211.02 tons of ore.

A.—Historical Summary.

The following historical notes on the more important leases are supplementary to those in Chapter II.:—

The Kelpy, first occupied at the end of 1904 was held at intervals till 1913. In January, 1908, H. Reed and W. Hawker found on it a rich "alluvial" patch on which about 50 men worked for the

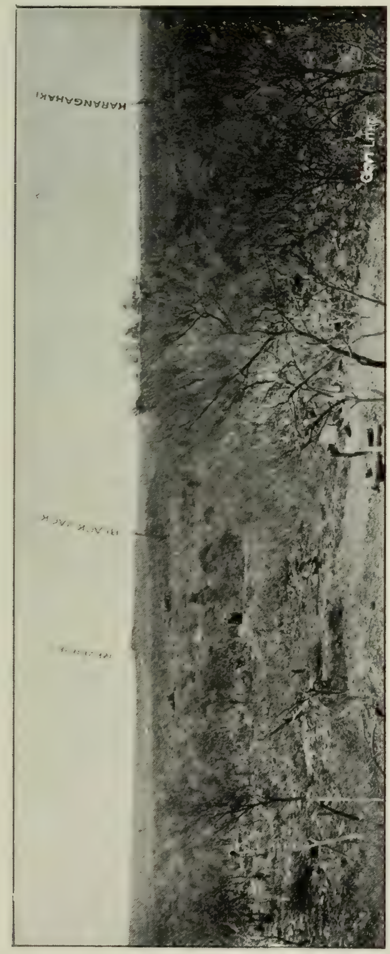


Fig. 65.

Photo.: E. de C. Clarke. Neg. 1395.

The Yaloginda Belt, looking towards the old Revenue Mine from the Black Jack Group.

rest of the year and from which 900 or 1,000ozs. are said to have been taken. The neighbouring leases were pegged during this time, but little gold seems to have come either from them or from the vein-workings on the Kelpy.

The Batavia was applied for in January, 1905, by J. M. Young and C. M. and J. A. Roberts. It passed through many hands, most work being done by Messenger and party in 1907 and 1908. During 1909, when the lease was held by a syndicate, there was even rumour of proposals to erect a winding-engine and battery.

The Rocklee was first leased late in 1906 to F. Henry and J. Clarke and was worked fairly continuously for six years, since when little has been done. In 1910 a 10-head mill was installed which still occasionally crushes for Yaloginda prospectors.

The Revenue North, pegged by A. E. Sainsbury and party in 1904 was held by various people till 1912, since when it has been vacant.

The Revenue South, taken up by D. A. Campbell and party in 1904, was held under various names until 1908.

The Revenue was applied for in July, 1904, by J. A. and C. M. Roberts and J. Dunn, passed through a number of hands and was last occupied by J. W. Worthington in 1912. In 1908 a Cornish lift and accessories were installed, but little used, disagreement among the shareholders causing the abandonment of a promising venture—the exploration of the rich "pipe" at depth.

The Two Bells Leases.—In the latter part of 1906, J. Gordon, J. Toohy and others took up the Two Bells lease and J. Gregson and others the Two Bells North. Both were held by various parties until forfeited in 1914, at which time they, with the Two Bells East, were leased to the "New Santa Claus G.M. Co., Ltd."

The Black Jack Group.—In October, 1908, F. Cook and a party of five found an "alluvial" patch (from which 200 ozs. were obtained), and immediately applied for the Black Jack. They afterwards found a very rich "leader," from which each of the party is said to have made £1,500 in a very short time. The main shaft was sunk to 100ft. but little ore was obtained below 30ft. Several leases were pegged south of the Black Jack and a good deal of shallow prospecting done, but except the Black Jack South, applied for at the same time as the Black Jack by H. McIntosh, which yielded a "dab" of $2\frac{1}{2}$cwt. for 60oz., the results were poor. By October, 1912, all leases in this group had been abandoned and no work beyond desultory prospecting has since been done. A lease (Red Jack, 841N) west of the Black Jack South is credited in 1909 with 4.85oz. from two tons of ore.

B.—Geology.

1. *Country.*—The bulk of the Yaloginda country is made up of sheared rocks, which strike N.N.E. and generally dip S.E. at about 70°.

(a) *Hornblende Schists.*—These rocks have been mined only in the Batavia and adjoining leases, but are well developed west of the Yaloginda Belt (*see* page 68). The shear-planes are vertical

or dip very steeply in some places east, in others west. An account of the hornblende schists will be found in Chapters IV. and VII.

(b) *Sheared Amphibolites.*—Almost all the workings of the Yaloginda Belt are in these rocks, although their proneness to weathering makes certain identification often impossible. Ironstaining and bleaching are particularly noticeable in the Black Jack Group. Thus in the west cross-cut off shaft 8 (Plate XXIII.), the schist has for 10 feet been changed into a black compact ironstone which would popularly be described as a jasper bar. When least weathered, these rocks are grey-green and strongly sheared. At first glance they show some resemblance to the "flecked schists" of the Queen of the Hill and other mines, but in the latter case the flecks appear to be of different material from the rest of the rock.

As in the Paddy's Flat Belt, so at Yaloginda, finer-grained types of these sheared (doleritic) amphibolites occur, the finer changing into the coarser along the strike. Comparison of the Yaloginda sheared amphibolites with greenstones from other parts of the Area (*see* Chapters IV. and VII. and Fig. 25) leads to the conclusion that they and the hornblende schists have a common origin.

(c) *Massive Amphibolites* (?).—Small areas of these massive rocks of doubtful nature (*see* above, pp. 68, 100, etc.) occur in this belt. It is possible that they are really ultrabasic rocks of the type next described.

(d) *Talc Serpentine* (?).— $\left[\frac{1}{345}\right]$ from the S.W. corner of the Kelpy South lease is a fibrous chlorite tremolite rock and is possibly an altered talc serpentine like $\left[\frac{1}{178}\right]$ from the Karangahaki.

(e) *Albite Porphyry.*—The white, sugary-grained rock from shaft 25, near the Kelpy lease is an albite porphyry, and probably is part of the dyke which outcrops to the north (47d) and south ($\left[\frac{1}{291}\right]$ and $\left[\frac{1}{108}\right]$.)

In shafts 33 and 34 (North Revenue Extended) the highly bleached schist has the characters usually shown underground in the Area by sheared rocks near a porphyry dyke. If such a dyke exists here, however, it has not yet been cut in the workings.

(f) *Jasper Bars.*—The positions of most, but not all of these features are indicated on Plates XXII. and XXIII. They run parallel to the veins and planes of shearing. In the few places where these jasper bars can be followed below ground they do not persist to water-level and appear to be merely zones of sheared amphibolite, containing unusually many quartz stringers, along which meteoric water, carrying salts of iron, etc., moved and deposited some of its minerals more readily than elsewhere (*see* further, page 85).

Jasper bars appear to have had no influence on gold-deposition in the Yaloginda Belt proper.

The gold-occurrences in the Black Jack Group, however, where there is apparently a close connection between the auriferous veins and the jasper bars may be described here:—

The *Black Jack Vein* was a band of "sandy" quartz, a few inches wide, lying west of an "ironstone bar." Both bar and vein dipped east at about 60°, and, in the branch drive shown, probably received a flat spur dipping S.E. at 25°. Gold was obtained, according to report, very abundantly from a shoot 15 feet long, extending from the surface to a depth of 15 feet, below which there was a blank for 15 feet. At a depth of 30 feet 9 tons were taken out, 68lbs. of which yielded, it is said, 476 ounces.

The Black Jack South Vein.—Very little can now be seen of this. Its "track" is apparently a floury seam of limonite, the course of which is marked as the vein on the map (Pl. XXIII.). At the north end of shaft 12 workings, a lens of white, glassy porous quartz occurs on the hanging-wall of the limonite seam, and is evidently due to replacement of the country (*see* Fig. 71).

The vein in shaft 21 has much the same character as the Black Jack South vein.

The inconstancy of veins in the Black Jack Group is illustrated in Fig. 71, No. 2. Although the vein figured dies out altogether below, it can be followed some distance horizontally.

Table showing the Yield of the Black Jack Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1908 ..	Black Jack, 834N	9·00	1,095·21
		..	*332·86
1909 ..	Do.	10·00	17·59
	Total	**19·00**	**1,445·66**

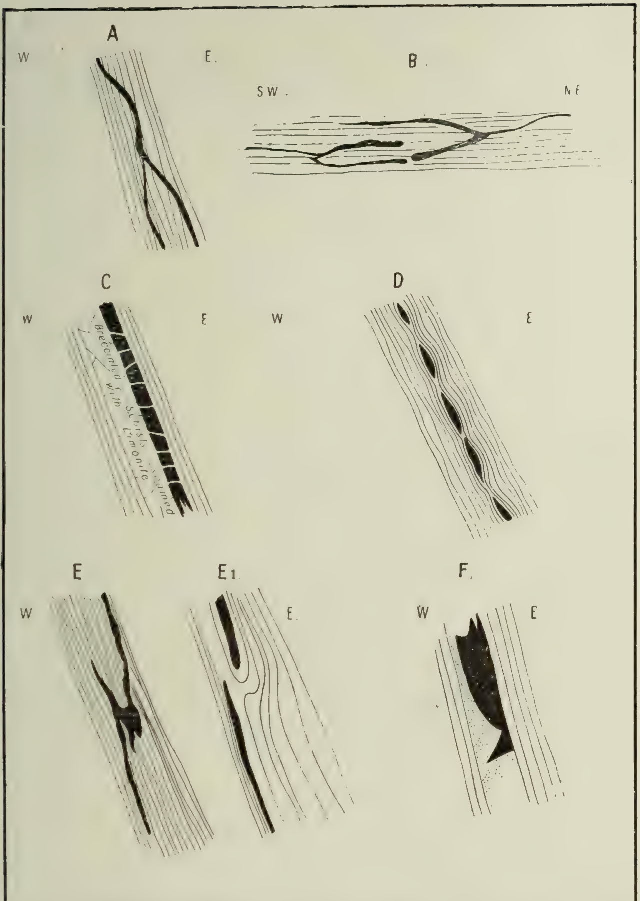
* Dollied and specimens.

Table showing the Yield of the Black Jack South Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1909 ..	Black Jack South, 833N	·10	73·81
1910 ..	Do.	9·50	39·91
1910 ..	Great Jack, 924N	24·50	5·83
1911 ..	Black Jack South, 833N	..	*59·24
	Total	**34·10**	**178·79**

* Dollied and specimens.

Fig. 66.



Typical Sections of Yaloginda Veins.

Scale: 12ft. = 1in.

A. Yaloginda Belt, Shaft 6—Branching vein—section.
B. Yaloginda Belt, Shaft 22—Branching vein—plan.
C. Yaloginda Belt, Shaft 43—North Revenue Vein—section.
D. Yaloginda Belt, Shaft 65—Ecrin Vein—section.
E. & E1. Yaloginda Belt—Sections of Rocklee Vein in 73ft. level and below 45ft. level.
F. Yaloginda Belt, Shaft 85—Relation between compact and "sugary" quartz.

2. *Veins.*—The ore-bodies of Yaloginda are, with the exception of the Black Jack Veins, lenticular quartz veins, parallel to the planes of shearing. They are due rather to replacement of the country, than to the filling of open fissures (*see* Figs. 66 and 71).

They dip east almost without exception. Strong slickensiding is nearly always visible in the rocks forming the hanging- and foot-walls, showing that movement took place along the vein-fissure before filling. The striae nearly always dip north at about 45°.

The veins are mapped as more continuous and uniform than they really are. The largest "kidneys" now left are seldom more than two feet thick and are usually mere stringers, frequently dying out and re-appearing further on in the same, or a neighbouring, shear-plane. In some places, white stringers transverse to the shear-planes are fairly abundant, are apparently quite barren, and are cut by the auriferous veins. They, therefore, belong to a period of barren quartz-injection later than the shearing and earlier than the auriferous solutions.

On the other hand at the north end of the 120ft. level on the Revenue North, a 6in. iron-stained quartz vein cuts across the shear-planes and the auriferous quartz, dipping west at 35°.

Some notes regarding individual veins may be added:—

(a) *Batavia* (Pl. XXII., sheet 1).—The largest lens of quartz, seen in shaft H, varies in thickness from three feet to one foot, and is only slightly greater in length and depth. There is a fairly continuous zone of quartz-impregnated country between H and J, but, beyond these, quartz is scarce. There is some stoping off J, and 30 tons, averaging 9dwt. per ton, are reported from I. The country in I shaft shows pyrite and is said to yield prospects.

The Batavia Group is difficult to mine owing to the hardness of the country and the smallness and irregularity of the veins.

Table showing the Yield of the Batavia Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1905 ..	Batavia, 578N	16·00	14·17
1906 ..	Do.	41·00	68·73
1907 ..	Do.	79·00	72·32
1910 ..	Do.	20·00	8·95
			*1·90
1913 ..	Rejected 1240N (former 578N) ..	120·00	14·53
	Total	**276·00**	**180·60**

* Dollied and specimens.

(b) *Kelpy and neighbouring veins* (Pl. XXII., sheets 1 and 2).—The Kelpy vein is in two sections—the southern, between shafts 29 and 31, is traceable for 100 feet horizontally and 40 feet verti-

cally. The northern, from which the gold of the alluvial patch came, has been followed for 200 feet x 90 feet, between shafts 17 and 22. Shafts 9 and 10 are also probably on this vein.

Three other lines of vein occur near the Kelpy—an eastern, traced for 150 feet x 50 feet, a middle, traced for 50 feet x 20 feet, and a small vein in shaft 13, which dips *west* at about 40°.

The total amount of stoping on all these veins is quite insignificant, but the bulk of the gold has come from the Kelpy and middle veins.

Table showing the Yield of the Kelpy Veins.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1905 ..	Kelpy South, 579N	10·50	13·22
1908 ..	Golden Calf, 759N (former 579N) ..	25·00	13·02
1910 ..	Kelpy, 771N	70·00	31·28
	Total	**105·50**	**57·52**

(c) *Revenue North or Brand's Vein* (Pls. XXV. and XXII., sheet 2).

The main work is in the south part of 541N, where the vein has been followed for 260 feet x 120 feet. Its remnants do not exceed one foot in thickness, and it has badly defined hanging- and footwalls. Probably the same vein is in shafts 35 and 36. Shaft 35 is at the junction of a "leader" with the main vein. G. Hawker is said to have followed this junction down to 90 feet and to have taken out 12 tons of quartz averaging 11½ozs. per ton. Shaft 36 gave 12 tons for an average of 14dwt. per ton.

*Table showing the Yield of the Revenue North Vein.**

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1904 ..	Revenue, North, 541N	20·75	10·30
1905 ..	Do. do.	28·25	15·34
1906 ..	Do. do.	22·00	18·91
1907 ..	Do. do.	188·50	89·00
1908 ..	Do. do.	76·00	23·55
1909 ..	Do. do.	184·00	66·24
1910 ..	Do. do.	236·00	239·38
1911 ..	Do. do.	122·58	62·59
1912 ..	Do. do.	82·75	52·71
	Total	**960·83**	**578·02**

* On the Revenue North Lease are workings on both the Revenue North and Revenue Veins, but very little ore appears to have been crushed from the latter.

(d) *The Revenue West Vein* (Pl. XXII., sheet 3) has been followed for 400 feet x 54 feet, and a probable northern continuation is found in shaft 50. Except in one or two bulges, it is barely one foot thick. Prospects, it is said, can be obtained by panning off the schist bordering on the vein even when the schist is apparently devoid of quartz.

Table showing the Yield of the Revenue West Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1904 ..	Revenue West, 534N	36·50	12·54
1905 ..	Do.	31·00	. 1·91
	Total	**67·50**	**24·45**

(e) *The Ecrin Vein* (Pl. XXII., sheet 3) has been followed for 350 feet x 85 feet. A possible north continuation is in shaft 62, where a shear-plane with little quartz, but with flat leaders on both sides has been followed. The quartz is in some places white and glassy, in others sandy. Otherwise this is like the West Revenue Vein. Ore has been taken mainly above the 42ft. level and for 20 feet above the 75ft. level in shaft 67.

The only recorded yield is 17.24oz. from 46.00 tons in 1900.

(f) *Revenue Vein* (Pls. XXII., sheets 2 and 3, and XXV.).—Quartz thought to belong to this vein has been found outcropping or in workings over a distance of nearly 3,300 feet, and has in one place been followed to a depth of 230 feet.

In shafts 33 and 34 the quartz is either white and sandy, or glassy and is only a few inches thick. A small crushing averaging 11oz. per ton is said to have been taken from shaft 33.

In shafts 45 and 46, the vein is just as small and irregular, and does not appear to have yielded any ore.

Between shafts 45 and 54, it has been uncovered at short intervals and is apparently a fairly strong body of quartz.

At the north end of the main workings the vein is 2in. to 6in. of granular but coherent quartz stained with iron oxide. At the south end, it increases in width to one foot. It lies, generally towards the hanging-wall side, in a zone of strongly sheared country two or three feet wide. It is met by a west-dipping vein—probably of later date—at the south end of the main workings.

Its supposed southern continuation has assumed rather the character of a "lode formation," there being, in shafts 63 and 64, two well-marked walls about three feet apart, containing bleached schist with a few quartz stringers.

The workings off shaft 63 were once more extensive, and are said to have been occasioned by the finding of a single "floater" containing 6 or 7 ounces of gold.

The Revenue "pipe" of gold was found at the surface in shaft 54 and appeared to end at the 30ft. level, for which reason the first lessees abandoned work. Their successors drove 30 feet south at the 30ft. level and found the pipe again. From this point it was followed down till it crossed the main shaft at 230 feet. The pipe was one foot wide and is said to have averaged 7ozs. to the pound. Although the vein was stoped for 50 feet on each side of the rich quartz, it is reported to have been quite barren. No suggestion as to the origin of this shoot can be offered. It is said that in its neighbourhood, the vein showed joints which ran very obliquely to the strike of the vein and carried as much as one inch of gouge.

Table showing the Yield of the Revenue Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1904 ..	Revenue South, 551N (later 744N) ..	38·25	30·09
1905 ..	Do. do. do. ..	75·50	39·96
1905 ..	Revenue North Extended, 556N ..	..	*4·87
1905 ..	Revenue, 531N	·37	1,173·55
1906 ..	Do.	9·38	1,903·38
1907 ..	Do.	·10	1,008·67
1908 ..	Do.	5·40	604·38
	Total	**129·00**	**4,764·90**

* Dollied and specimens.

(*g*) *Rocklee Vein* (Pl. XXII., sheet 2).—This has been followed horizontally for about 400 feet, and in one place mined to a depth of 240 feet. Its probable extensions are shown on the plan. It is a typical vein of the Yaloginda type, rarely exceeding one foot in width, and in part at least formed by replacement (Fig. 66, E and F). Southwards (shaft 48) the vein breaks up into small stringers and seems to pass into one of the jasper bars.

It is reported that general samples along the cross-cuts off the main shaft and shaft 40, where the schists show many parallel

stringers, assayed 3dwt. per ton. However, a general sample (lab. no. 7109) taken by the writer in the first locality yielded only a trace (less than 9 grains per ton) of gold, and another (lab. no. 7710) of the quartz stringers in the same cross-cut gave the same result.

Table showing the Yield of the Rocklee Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1907 ..	Rocklee, 709N	104·00	86·73
1908 ..	Revenue Proprietary, 770N	10·50	8·99
1909 ..	Rocklee, 709N	232·00	186·57
1909 ..	Rocklee South, 857N	41·00	34·85
1909 ..	Rocklee Leases, 709N and 857N ..	..	*·44
	Do. do.	68·00	56·81
1910 ..	Do. do.	225·50	107·01
1911 ..	Do. do.	194·31	150·28
1914 ..	Pariah (part of former 709N), 1260N ..	30·00	5·38
	Total	**905·31**	**637·06**

* Dollied and specimens.

(h) *Two Bells Veins* (Pl. XXII., sheet 4). Three parallel veins have been worked in the Two Bells and Two Bells North Leases.

(i.) *The North Vein.* This gave all the ore from the Two Bells North lease. It can be traced south for about 450 feet to the cross-cut off the main shaft (where it is breaking up), and has been worked to a depth of 70 feet. From the shape of the stopes (Pl. XXV.) values would seem to have been in a south-pitching shoot.

(ii) *The Middle Vein* has produced the Two Bells ore. Owing to the state of the workings it is impossible to give any account of the vein or the probable distribution of values. In the workings off the main shaft at 140ft. the vein is represented by an 8ft. zone of sheared and contorted schist in which run several irregular quartz veins.

(iii) *The South Vein* has given some ore from shafts 91 and 92. Its north extension can be traced in the 140ft. level on the main shaft and in the east cross-cut off shaft 96. Beyond shaft 88 its southern course is unknown, but possibly it is cut in shaft 87, where iron-stained bands in the schist carry small quartz stringers.

The Two Bells Veins resemble in every way the Kelpy and other Yaloginda veins.

Table showing the Yield of the Two Bells Veins.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1906 ..	Two Bells, 675N	24·00	42·00
1907 ..	Do.	81·50	92·84
1907 ..	Two Bells North, 695N	47·00	19·65
1909 ..	Two Bells, 675N	49·00	65·86
	Two Bells North, 695N	20·00	40·86
	Saracen, 845N	60·00	9·93
1910 ..	Yaloginda Consols G.M. Co., Ltd., 675N and 859N	58·00	31·16
1910 ..	Two Bells North, 695N	82·00	72·57
1910 ..	Do.	..	*1·75
1911 ..	Do.	84·72	77·53
1911 ..	Do.	..	*4·38
1912 ..	Do.	60·41	41·78
1914 ..	New Santa Claus G.M. Co., Ltd., 675N and 859N	50·00	10·15
	Total	**616·63**	**510·46**

* Dollied and specimens.

(i.) *Other Veins.*

(i.) Shaft 38 (Pl. XXII., sheet 2) shows 2 feet of quartz in highly bleached schist. This is on the Revenue East ground, and apparently produced the crushing of 1,046.44oz. from 18.15 tons recorded from that lease in 1904. This shaft is said to have produced, in later days, a crushing (tonnage unknown) averaging 5dwt. per ton.

(ii.) The veins in shafts 2 and 3 (sheet 2), in shaft 56 (sheet 3) (followed to a depth of 61ft.), and that in shafts 82 and 84 (sheet 4), which may be traced the whole length of the Revenue Consolidated lease, deserve only mention.

(iii.) Shaft 85 (sheet 4). The vein in this shaft belongs really to the Black Jack Group. It is 1ft. 6in. wide, but shows a bulge 3ft. wide in the hanging-wall, which is filled with brecciated quartz. Its quartz is in some places blue and compact, in others sugary, and in the latter case is thickly peppered with small pyrite crystals. The compact blue quartz apparently results from the re-cementing of the sugary variety (Fig. 66, F).

North of the Black Jack a number of similar but smaller veins have been opened up, with no results.

(iv.) On and near the Lady Mary lease (Pl. XXIV., sheet 1), taken up in 1908 by J. M. Gibbons and party and forfeited three years later, are some small workings which disclose veins and rocks of the usual Yaloginda type, and also a cross-vein dipping S.W. at a low angle.

Table showing the Yield of the Lady Mary Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1909 ..	Lady Mary, 897N	34·00	20·02
1911 ..	Do.	43·00	11·04
	Total	**77·00**	**31·06**

XIII.—KARANGAHAKI BELT. (Plate XXIV. and Figs. 68 and 69.)

This belt covers the strip extending from the Karangahaki to the Mystery (1236N), a distance of about two miles. It differs from the Yaloginda Belt mainly in the character of the auriferous bodies.

A.—Historical Summary.

At the beginning of 1902, the New Murchison King Co. and several other parties, including J. A. and C. M. Roberts, successively held the Karangahaki ground (Plate XXIV., sheet 2). T. N. Kirkland met with the greatest success, and in 1908 his lease was transferred to F. B. Trude, who formed a company known as the Karangahaki Mines, Ltd. A ten-head mill, cyanide plant, etc., were installed and towards the end of 1909, the mine was reported to have repaid the whole cost of machinery and development and to be employing 50 men. However, from all accounts, the lode was disappointing when opened out at 300 feet early in 1911. In consequence, the plant was sold and nothing has been done on the ground since.

The Gibraltar lease, originally held in 1902 by the Murchison King G.M. Co., under the name of Phantom, was most worked by C. H. Ord and party, by whom a battery was erected in 1909. Little ore was crushed, partly, it is said, owing to difficulty in obtaining water, and the battery was removed to the Hornsby (*see* page 201).

The Great Oversight lease (731N) (Plate XXIV., sheet 3) was held from 1907 to 1911 by D. Henderson and party, since when little if anything has been done.

Rhen's (formerly Henderson's or McColl's Prospecting Area (Fig. 68) has been worked at intervals since 1906, but with no very striking results.

Gold on the Mystery (1236N) (Fig. 69) was discovered early in 1913 and the lease, originally held by C. Ward and O. Hart, passed to T. Kirkland and party, who worked it for about two years

B.—Geology.

Except for the mode of gold occurrence, there is a general likeness to the Yaloginda Belt.

1. *Country.*—This consists, so far as known, of—

(a) *Sheared Amphibolite* of the same character as at Yaloginda and forming the bulk of the country.

Fig. 67.

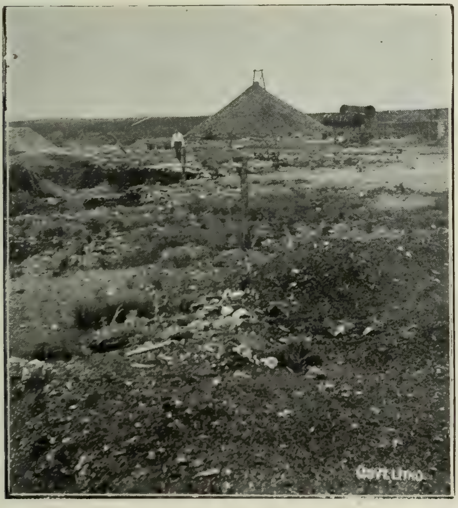


Photo.: E. de C. Clarke. Neg. 1213.

Karangahaki G.M.: Site of the Workings.

(b) *Talc Serpentine* $\left[\frac{1}{178}\right]$ in shaft 2 at north end of Karangahaki workings (*see* Chapter VII., page 256).

(c) *Quartz Porphyry*—$\left[\frac{1}{104}\right]$ and $\left[\frac{1}{105}\right]$ the Maranui dyke (Chapter IV., page 57, and VII., page 224).

(d) *A Jasper Bar* is said* to occur on the Karangahaki lease and to persist to at least 200ft., where it is represented by "laminated quartzite and dark jasper," and west of which a good supply of water was obtained.

2. *Lodes.*—The workings of the Karangahaki Belt, excluding the Maranui Group, which is placed on Plate XXIV. for convenience in mapping, are on one (or two) lines of lode.

(a) *Karangahaki Lode* (Plate XXIV., sheet 2).—By this name will be designated only the ore-deposit of the Karangahaki Mine.

* Montgomery Rep. Min. Prog. Murchison and Peak Hill Goldfields, p. 51.

The workings (except the cross-cut and a little of the drive at 100ft.) are now inaccessible. According to the State Mining Engineer's reports* the gold was obtained from a lenticular vein lying in an older "formation" (presumably a zone of shattering) which was 4ft. to 10ft. wide, dipped east at about 45° and the smooth boundary walls of which were seen in cross-cuts. Mr. Montgomery considered that the auriferous quartz body would, even when first formed, be of less regular shape than if it had been formed in solid country, and to this primary irregularity he found there had been added the effects of a later faulting along the old zone of shattering which resulted in much disruption of the enclosed quartz vein.

Judging by the 300ft. of resultless cross-cutting off shafts 1 and 2 (Plate XXIII., Sheet 1), the Karangahaki Lode dies out northwards. Its possible southern continuation will be considered in the next sections.

Table showing the Yield of the Karangahaki Lode.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1903 ..	Phantom, 416N	243·00	218·16
1904 ..	Eastern Revenue, 545N (former 416N)	15·50	17·85
1906 ..	Karangahaki, 666N	283·00	558·00
1907 ..	Do.	44·50	38·19
1908 ..	Do.	2,232·00	1,174·21
1909 ..	Do.	8,771·00	3,963·87
1910 ..	Do.	1,297·00	466·96
	Total	**12,886·00**	**6,437·24**

(b) *Gibraltar Lode* (Plate XXIV., sheet 2). (i.) Off the Gibraltar main shaft the "lode" is at least 30ft. wide and consists of white kaolinised and sericitic rock abundantly netted with quartz veins, which vary in width from several feet to mere threads. The lode has a clearly defined hanging-wall, the footwall has not been exposed. Owing to its highly decomposed state, micro-examination of the lode material did not yield very definite results. By its mode of occurrence, the lode would, however, appear to be a zone of the sheared amphibolites, which has been injected with quartz veins—probably extremely acid phases of a porphyry.

A sample was taken across the lode at the 44ft. level, which yielded an assay (Lab. No. 7111) of 1dwt. 22gr. per ton. However,

* Rep. Min. Prog. Murchison and Peak Hill Goldfields. pp. 40 and 41.

100 tons of ore from the central shaft taken without special picking is stated to have yielded at the rate of 4½dwt., with tailings assaying 1½ dwt. per ton.*

At the north end of the 44ft. level, the lode is apparently cut off by a fault, as shown on the plan, and the "many quartz outcrops" just north and west might reasonably be its northern continuation. But in shafts 5 and 6 is a formation usually regarded as the Karangahaki Lode, which is of the same type as the Gibraltar. Also the Gibraltar lode is in alignment with the Karangahaki Lode. Either, then, the Karangahaki is the continuation of the Gibraltar, differing from it in having a main vein of later date and higher tenor, or (less likely) the two lodes are independent.

Table showing the Yield of the Gibraltar Lode.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1908 ..	Gibraltar Leases 708N, 731N	100·00	19·78
1909 ..	Do. do.	106·00	18·60
1910 ..	Do. do.	420·50	58·73
	Total	**626·50**	**97·11**

(ii.) *Southward Continuation.* In shaft 10 (Plate XXIV., sheet 2) the transition from country to lode is more gradual. Quartz stringers parallel to the planes of schistosity are seen right away from the lode, causing some sericitisation of the adjoining rock; both veins and sericitisation become more noticeable as the lode is approached.

In shafts 11 to 13 (sheet 3), and in the potholes on the south boundary of the Great Oversight lease, a similar "lode formation" is shown, but no defined walls to the body have been found, and cross-veins running E.N.E. seem to play an important part in the gold deposition.

Further south on Rhen's P.A. (for position *see* Plate IV., sheet B, for detail, Fig. 68) a similar type of deposit has been worked. Here, again, no definite walls to the "formation" have been discovered. It seems probable that the main "formation" running from the "open-cut" is intersected a little north of No. 1 shaft by a secondary line, running generally N.W., along which most of the work has been done.

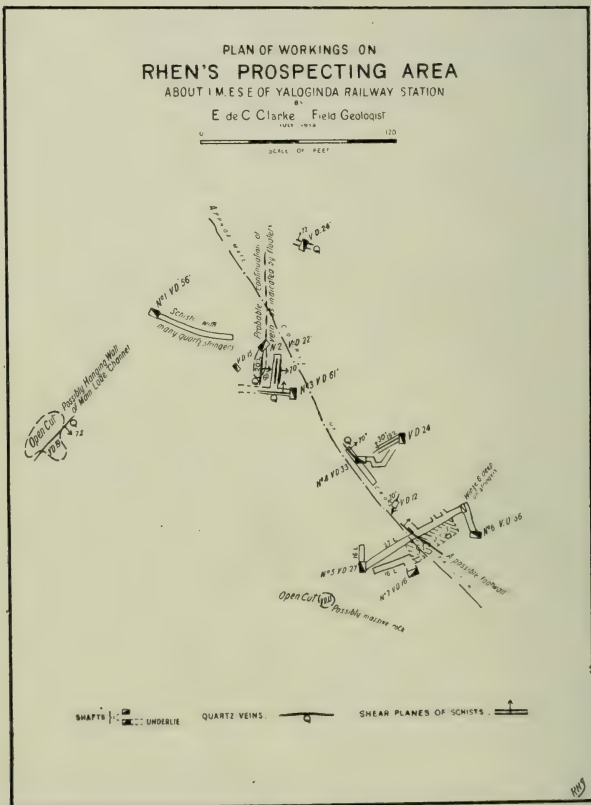
A little north of Rhen's, large quartz veins, with the same north-westerly course, outcrop.

A continuation of the same type of lode-formation is most probably that worked on the Mystery Lease (Fig. 69). In this

* Montgomery op. cit. p. 42.

case, all the work has been done on cross-veins, the complicated character of which is indicated in the figure. It seems that the principal shoot of gold has made along the junction of two veins, one running somewhat north, the other somewhat south, of east, and dipping north at about 70° and 45° respectively.

Fig. 68.



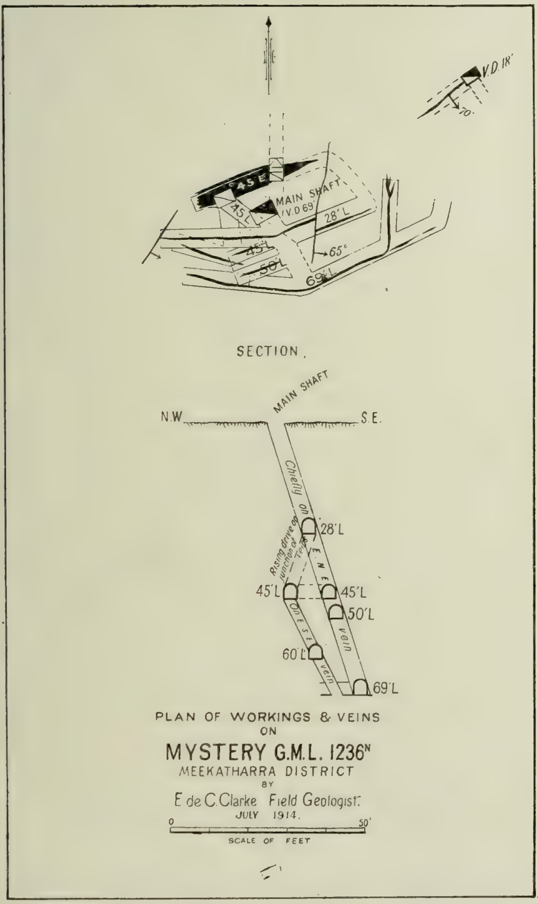
The longer edges of the plan run north and south.

Table showing the Yield of the Mystery Lease.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1913 ..	Mystery, 1236N	139·00	90·30
1914 ..	Do.	321·10	240·44
	Total	**460·10**	**330·74**

(c) *On the Karangahaki East Lease* are some small workings on a west-dipping vein. The effect of the neighbouring Maranui Porphyry Dyke is seen in the characteristic alteration of the sheared amphibolites.

Fig. 69.



XIV.—OTHER YALOGINDA WORKINGS.

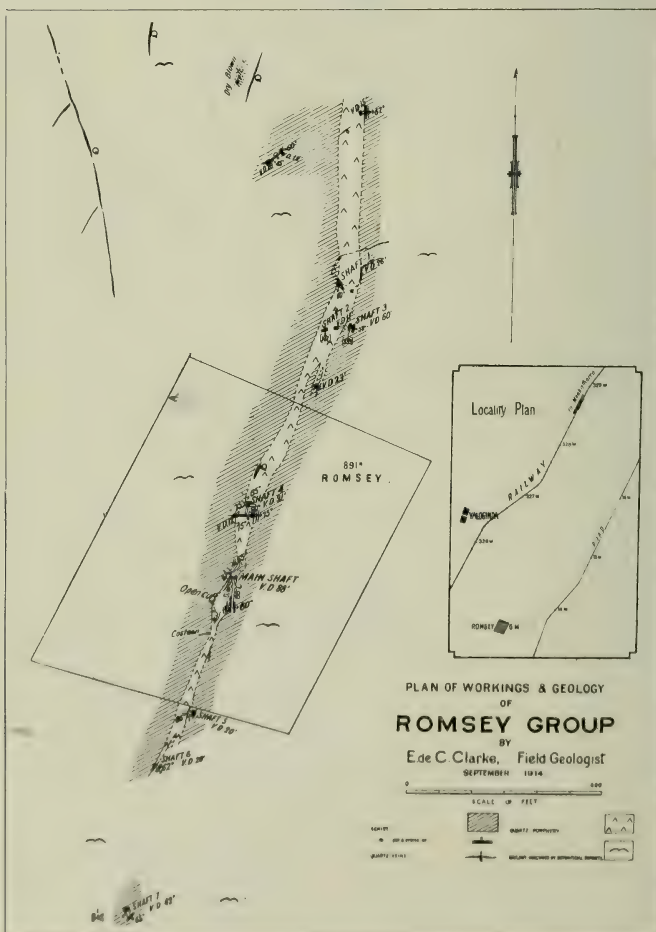
A. Maranui Group (Plate XXIV., sheet 3).

1. *History, etc.* On this group, which is a quarter of a mile south of the Karangahaki East Lease, gold was first discovered in 1909. Chief interest in the group was owned by C. and J. Roberts. The leases were surrendered in 1913.

Table showing the Yield of the Maranui Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1909 ..	Maranui, 899N	52·00	108·29
1910 ..	Do.	108·00	100·95
1911 ..	Do.	52·00	51·87
	Total	**212·00**	**261·11**

Fig. 70.



2. *Geology*, (a) *Country*. The best specimens $[\frac{1}{349}]$ obtainable were much weathered, but are probably of the same type as the Yaloginda sheared amphibolites, though rather less sheared, and in places almost unsheared.

In the more massive portions (*e.g.*, shaft 6) weathering along the close-set curving joint-planes causes the rock to look like an accumulation of pebbles. It may be mentioned here that two shafts near the 14 mile-post on the Nannine Road are reputed to be sunk at least 60 feet in "alluvial" wash, and hopes have therefore been entertained that if bottom could be reached "deep leads" would be found. These shafts are, however, sunk in the same false wash as shaft 6 above, and are on the same line of strike.

(b) *Vein*. The Maranui vein varies from a mere thread to four feet in width. It shows a good many minor dislocations (Fig. 71, no. 6) in addition to more considerable faulting (*see* plan). The quartz is bluish in colour and vughy. The shear-plane or "track" of the vein can be traced some distance south of the termination of the vein. The hanging- and footwall country are traversed by many stringers and fine leaves of quartz.

B. Romsey Group (Fig. 70).

1. *History, etc.* The Romsey (G.M.L. 891N) is about one and a quarter miles S.S.E. of Yaloginda Railway Station. It was pegged by M. O'Brien in June, 1909, passed through a number of hands, and was forfeited in July, 1915.

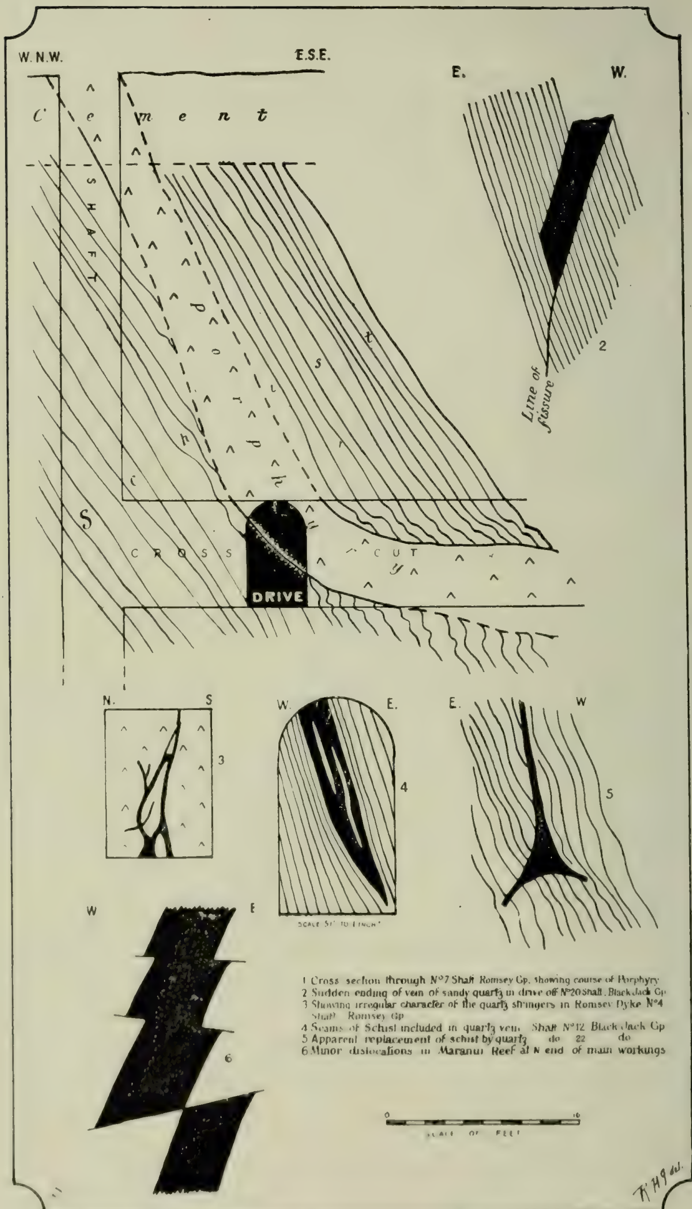
During June and July, 1914, some excitement was caused by the discovery of a rich vein just north of the Romsey near the site of some workings, from which, in 1910, "Port Darwin Mick" got two trial parcels, which averaged 14 and 20 dwt. respectively. It was soon realised, however, that most of the values in the "lode 50 or 60 feet wide and traceable for two miles" were confined to small cross-veins, and interest in the neighbourhood waned.

Table showing the Yield of the Romsey Lode.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1909	Romsey, 891N	166·00	100·85
1910	Do.	181·00	73·39
1911	Do.	143·03	47·97
1912	Do.	1,033·00	206·47
	Do.	..	*28·77
1913	Do.	2,617·00	652·80
1914	Do.	131·50	138·98
	Total	**4,271·53**	**1,249·23**

* Dollied and specimens.

Fig. 71.



Types of Veins and Lodes near Yaloginda.

2. *Geology.* (a) *Schists.* These highly decomposed rocks are sheared amphibolites of the type found in the Yaloginda Belt. S me $\left[\frac{1}{340}\right]$ are of the finer chloritic slate type.

(b) *Quartz Porphyry.* The course of this dyke is shown in Fig. 70. The rock can only be recognised underground and the boundaries are conjectural where they do not cross workings. The irregular course of the dyke in some places is shown in shaft 7 (Fig. 71, No. 1).

Under the microscope, this rock proves to be a fine-grained chloritic porphyry $\left[\frac{1}{106}, \frac{1}{107}\right]$ or a chloritic albite porphyry or porphyrite $\left[\frac{1}{111}, \frac{1}{339}\right]$. It was noted that a quartz veinlet (of coarse plates full of fluid pores, and therefore deposited from a hot solution) in the porphyry, had an edging of fine quartz mozaic like a chilled margin. That the quartz veins are later than the porphyry (probably its last-consolidated, most acid phase) is also seen underground (Fig. 23) where the many veins, usually transverse to the course of the dyke, sometimes cross without defection from the porphyry into the schists—which they do not penetrate far and in which they induce sericitisation, as noted of veins in the Gibraltar Lode.

The gold of the Romsey Group comes from these cross-veins, more particularly those which are fairly regular in strike and dip. They are said to be specially rich where intersected by longitudinal veins and to carry gold only when in the porphyry. Probably, however, to judge from the workings at the north end of the group, they are occasionally auriferous where they have penetrated the schists.

(c) *Northern Extension of Romsey Porphyry.*—At the "Cement Patch," about half a mile north of the Romsey (*see* Plate IV., sheet B), in two of the shafts, occur schists showing the bleaching and green-staining which are generally found in the Area to be signs of the nearness of a porphyry dyke. It is therefore possible that the Romsey dyke extends thus far north.

A few small veins are found at the Cement Patch, but the gold has all been obtained by milling the ferruginous laterite which covers the patch to a depth of at least 12 feet in places. A parcel (of unknown size) of this limonite crushed at Nannine is said to have averaged 11 or 12 dwt. per ton. However, a trial crushing of 14 tons made in 1914 yielded a total of only 2½oz.

C.—Lewes Priory Group (Fig. 72).

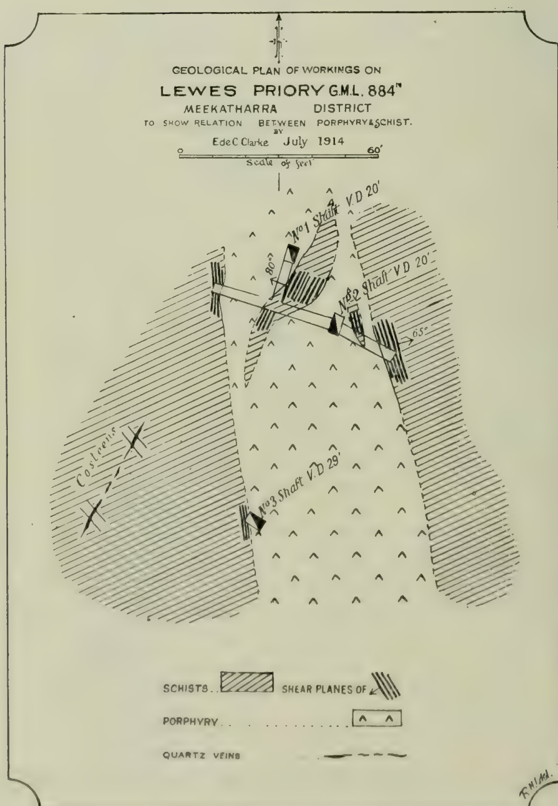
About a mile south of the Romsey, the Lewes Priory and two other leases were taken up in 1909, and held for about a year.

Table showing the Yield of the Problem, Lewes Castle, and Port Phillip Leases.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1909 ..	Lewes Castle, 883N	11·00	3·29
1911 ..	Port Phillip, 1053N	28·50	4·09
	Problem, 1062N	105·00	10·77
	Total	**144·50**	**18·15**

The little underground work done proves the existence in three shafts (Fig. 72) of a porphyry dyke like that in shaft 1 of the Hornsby Group (*see* below) and possibly forming a link between the Romsey and Hornsby dykes.

Fig. 72.



The gold occurrence (if any) in these shafts would appear to have been the same as in the Romsey.

D.—Hornsby Group (Fig. 73).

1. *History, etc.*—These workings are about a quarter of a mile west of the 12 mile-post on the Nannine Road.

The ground was taken up in 1909 by J. Gordon and party and worked till 1913. The strong flow of water is stated to have been the great difficulty in working the lease.

About 1911 the Gibraltar plant was erected here and public crushings undertaken.

Table showing the Yield of the Hornsby Vein.

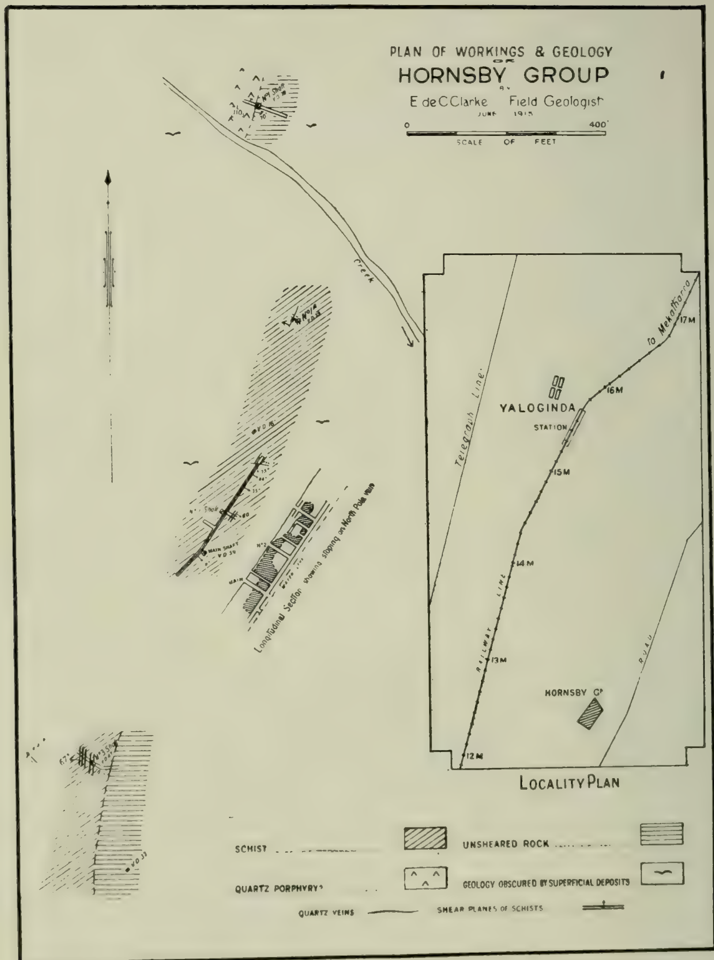
Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1910 ..	Hornsby (North Pole), 937N ..	89·00	38·36
1911 ..	Do. do.	323·00	90·35
1912 ..	Do. do.	63·00	41·02
1913 ..	Do. do.	30·00	8·73
	Total	**505·00**	**178·46**

2. *Geology.* (a) *Country.*—The rocks found underground, though highly decomposed, are evidently the same type as comparatively fresh rocks $\left[\frac{1}{336}, \frac{1}{337}, \frac{1}{346}\right]$, classified as sheared amphibolites, outcropping less than a quarter of a mile to the north. Two patches of the supposed "massive amphibolite" (*see* p. 68) also occur on this group.

In the west cross-cut off shaft 1 is a white, highly decomposed rock, netted with quartz veins and clearly separated from the "greenstone." Under the microscope, this rock is "more than probably the weathered remains of a quartz porphyry." Its probable connection with the Lewes Priory, and possibly the Romsey, porphyry has already been mentioned.

(b.) *Vein.*—The gold-bearing vein of this group strikes N.N.E., parallel to the planes of schistosity, is nearly vertical, and has an average thickness of about 1ft. 6in. At the south end it widens to three or four feet and apparently loses values, at the north end it is cut by a fault beyond which it has not been definitely found. The vein is strongly cross-jointed, the joints being occupied by gouge. Generally, it resembles the Maranui vein.

Fig. 73.



E.—New Chum Group.

The abandoned leases, New Chum and Her Royal Highness, situated within half a mile of the 324-mile post on the railway line, have a number of shallow shafts as indicated on Pl. IV., sheet B.

The "New Chum" (923N) was applied for in August, 1909, and, after passing through a number of hands, was forfeited in 1912. "Her Royal Highness" (1124N), applied for in the middle of 1911, was forfeited about a year later.

Table showing the Yield of the New Chum Vein.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	oz.
1909 ..	New Chum, 923N	8·00	51·15
1910 ..	Do.	..	*62·80
1910 ..	Do.	75·50	150·68
1911 ..	Do.	301·00	56·60
	Total	**384·50**	**321·23**

* Dollied and specimens.

The shafts (9 to 15) on 1124N apparently failed, despite much cross-cutting, to discover any auriferous body.

Those (1 to 8) on 923N are sunk along a very prominent quartz "blow" which, as shown on the map, can be traced for a considerable distance both north and south of the lease. According to report, the New Chum yielded a few small rich parcels.

A sample taken by the writer along the outcrop of the vein between shafts 1 and 4 was assayed (Lab. No. 7119) and yielded only a trace of gold per ton.

The general rule that "blows" do not live down is borne out in the "New Chum" workings, where the blow is seen to break up into stringers of quartz within 30 feet of the surface.

The country in both leases is $\left[\frac{1}{338}\right]$ a contorted foliated chloritic clayey schist, with here and there opaque granular patches of uncertain composition, also occasional mozaic patches enclosing quartz grains, rutile needles and colourless sericitic or chloritic patches. It is best classed with the sheared amphibolites of Yaloginda.

XV.—GOLD-PRODUCTION OF PROSPECTING AREAS, ETC.

The following gold-returns from the Area are not included in the preceding descriptions:—

Table showing the Yield of Sundry Claims (Prospecting Areas, etc.) at Garden Gully.

Year.	Ore crushed.	Gold therefrom.
	tons.	oz.
1901	12·00	41·34
1908	94·00	90·86
1909	54·50	63·16
1912	23·10	53·87
1913	..	*1·47
	16·00	9·30
1914	..	*1·85
Total ..	**199·60**	**261·85**

* Dollied and specimens.

Table showing the Yield of Sundry Claims (Prospecting Areas, etc.) at Meekatharra.

Year.	Remarks.	Ore crushed.	Gold therefrom.
		tons.	oz.
1899 ..	.. ..	28·00	94·72
1901 ..	.. ..	38·50	34·63
1902 ..	.. ..	105·00	55·29
1903 ..	.. ..	45·50	20·18
1904 ..	.. ..	14·75	6·86
1905 ..	.. ..	45·00	23·37
1906 ..	Alluvial	..	177·68
		36·00	19·21
1907 ..	.. ..	536·00	476·21
1908 ..	.. ..	326·60	98·18
1909 ..	.. ..	133·00	72·34
1910 ..	.. ..	289·50	154·37
1911 ..	.. ..	..	*3·67
		95·73	109·23
1912 ..	.. ..	..	*1·64
		152·26	51·24
1913 ..	.. ..	..	*6·52
		451·11	116·24
1914 ..	Alluvial	..	4·15
		..	*105·10
		130·10	67·64
	Total	**2,427·05**	**1,698·47**

* Dollied and specimens.

Table showing the Yield of Sundry Claims (Prospecting Areas, etc.) at Yaloginda.

Year.	Remarks.	Ore crushed.	Gold therefrom.
		tons.	oz.
1908 ..	.. ..	..	*6·00
		115·50	89·54
1909 ..	.. ..	..	*14·70
		212·65	277·11
1910 ..	.. ..	..	*15·83
		310·75	102·61
1911 ..	.. ..	92·99	31·72
1912 ..	Alluvial	..	3·71
		..	*82·38
		59·38	61·31
1913 ..	.. ..	..	*23·14
		188·90	204·58
1914 ..	Alluvial	..	7·18
		..	*89·29
		524·00	190·50
	Total	**1,504·17**	**1,199·60**

* Dollied and specimens.

Table showing the Yield of Tailings (Cyanided at State Battery, Meekatharra, and at Karangahaki Works) from Area generally.

Year.	Name of Battery.	Ore crushed.	Gold therefrom.	Silver therefrom.
		tons.	oz.	oz.
1903 ..	State Battery, Meekatharra	..	65·18	..
1904 ..	do. do.	*(14·00)	457·70	..
1905 ..	do. do.	..	748·59	..
1907 ..	do. do.	..	737·13	..
1908 ..	do. do.	..	1,585·83	..
1909 ..	do. do.	..	1,307·64	19·00
1910 ..	do. do.	..	1,040·31	..
	Karangahaki G.M. ..	..	42·06	..
1911 ..	State Battery, Meekatharra	..	1,333·94	..
1912 ..	do. do.	..	2,504·98	..
1913 ..	do. do.	..	112·29	..
	Total	***(14·00)**	**9,935·65**	**19·00**

* Not included in computing total tonnage for Area.

CHAPTER VII.

PETROLOGY.

By R. A. Farquharson.

I.—INTRODUCTION.

The investigation of the petrology of Meekatharra has proved a difficult undertaking. Broadly, speaking, the area examined consists of two portions, a central portion in which the majority of the most important mines occur, and in which the rocks have been extremely altered by both chemical and dynamic agencies, and an external zone, in which, though the rocks have been considerably altered by dynamic strain, they are still comparatively fresh and retain characters by which their original character is easily determinable. In the former, owing to the large number of mines, the multiplicity of rock varieties, the differences in texture, structure and composition, and to the degree of alteration by chloritisation, carbonation, talcicisation and kaolinisation of the rocks; the difficulty has been to correlate the specimens, and, thereby, to discover the actual distribution of rocks belonging originally to the same mass, and to determine their relations to contiguous rocks of a different type. In the latter, on the other hand, owing to the isolated occurrence of the outcrops, and to the fact that the intervening country between them is usually either reduced to the state of clay, or covered by a considerable thickness of over-burden, the difficulty has lain in determining the genetic and chronological connection between the outcrops. In the case particularly of the much altered

rocks, it has been only by the examination of a large number of specimens that any traces of original structure have been obtained in them. A very large proportion of them have been of the nature of clays, and, indeed, the determination of the geology of a considerable section of the central portion has been dependent in the discovery of relict structures indicative of their origin. Sections, however, prepared by ordinary processes, were found to be of little use. Either they were too thick and practically opaque to light, or, as a result of their softness and friability, they disappeared by attrition in the grinding process. In consequence, a modification of the process of preparation had to be evolved, and it was found that by special treatment of the rock with Canada balsam, it was possible to prepare sections even of the almost completely rotted rocks that preserved relics of original structure and were sufficiently thin for these to be clearly identified. Since more than a hundred sections had to be so prepared, a considerable expenditure of time was necessarily involved, but the results achieved have fully justified it, and have again exemplified the economic importance of the study of relict structures in the mining fields. The change, for example, in the direction of the strike of the Ingliston Extended dolerite, which, had it been known previously, would have saved much time and money spent in shaft sinking, has been determined from sections of rocks now reduced to clays, and it is safe to say that much of the geology of the country immediately to the east and west of the Paddy's Flat porphyry dyke has been elucidated by the investigation of sections almost of the character of clays.

In spite of the difficulties, however, by a careful co-ordination of the evidence derived from the field relations of the rocks with that derived from a comparative study of their mass and microscopic characters, the general geology of whole district and of the more important mines as illustrated by the maps accompanying this *Bulletin* has been rendered as clear as the circumstances under which the investigations have been carried out have permitted. In those cases, of course, in which evidence of field relations is vague or absent, microscopic evidence, assisted at times by chemical analysis, has necessarily alone determined the points at issue. Some questions, such as the relationship between the granite varieties are unsolved, and it is much to be regretted that, as they are questions rather of scientific than of any economic interest, and as it is at present necessary in geological survey work to regard the purely economic aspect, *i.e.*, the origin and distribution of the mineral resources, of paramount importance, they must continue to remain unsolved.

Altogether, about 600 slides have been examined. These have been cut chiefly from rocks collected by Mr. Clarke, but included

in the number are those from specimens collected previously by other members of the staff, especially by Messrs. A. Gibb Maitland and H. W. B. Talbot in 1910. For obvious reasons, however, only those specimens which best exhibit the important characters of the rocks have been described in the text.

Both before the inception of the present survey of the district, and during its course, the writer has been enabled to visit and examine many of the mines and much of the surrounding country, and thus to become familiar with the occurrence of the rocks and their appearance and character in the mass. These visits have very considerably facilitated the petrological investigations, and especially the correlation of the specimens.

The terms District, Area and Belt are used in the sense defined by Mr. Clarke in the introductory pages of the *Bulletin.*

2.—PREVIOUS LITERATURE.

The earliest remarks on the geology of the Meekatharra Field of any scientific value are contained in a Report on "The Geology and Mineral Resources of a part of the Murchison Goldfield," by C. G. Gibson, in Bulletin 14, G.S.W.A. On page 61 of this Report, Gibson states:—

The country in the immediate vicinity of Meekatharra Townsite consists of low, rough greenstone ridges, extending southerly for about two miles, when they give place to extensive plains covered with recent deposits ; westerly for three miles ; and northerly for two, when they are replaced by a large belt of granite trending about north-east ; easterly they extend indefinitely.

These greenstones are very much decomposed and weathered, so much so that it was impossible to obtain a specimen for determination, none of the mine workings being down below the zone of decomposition. Immediately to the east of the townsite is a wide belt of banded quartzite trending slightly east of north and forming a low ridge, on the highest point of which Luke's Trig. is situated . . . . . . The granite which occurs to the north and west of the townsite is a coarse-grained massive variety, extending northerly for five or six miles, and being for the most part covered with a considerable thickness of loose, sandy soil, with the rock occasionally outcropping as low bare ridges. Numerous dykes run out from this main body into the greenstones, which are considerably foliated in close proximity to them.

A section of a specimen of this granite taken from a spot about a mile north of the Havelock G.M.L., seen under the microscope, shows it to be a very similar rock to that occurring at Cue. . . . . .

A second large similar belt of granite occurs about 10 miles to the east of the townsite, trending north and south. . . . . ."

In his description of the mines he refers to the country rock in most cases as "a soft kaolinised greenstone."

In the Annual Progress Report of the Geological Survey for 1909,[1] Mr. H. P. Woodward published an article with the title "A

1. *Vide* Annual Reports, Dept. of Mines, 1909, pp. 165-166.

Preliminary Report on the Ore-bodies of Meekatharra." *Inter alia,* he states:—

The rocks of this belt consist for the most part of schistose greenstones much hydrated, intersected by dolerite, felspar porphyry and granitic dykes, and traversed parallel to the lines of banded ferruginous quartzites which evidently represent main lines of shearing, whilst upon the western side is a ridge of broken granitic hills. . . . . . .

So far as can be gathered by a comparatively cursory examination, the primary force which is responsible for the shearing in the Marmont, Fenian, and Ingliston Consols is a large intrusive mass of felspar porphyry at the south-east end of the first-mentioned mine. This mass is an igneous acid intrusion, in part a felspar porphyry consisting principally of albite and quartz, whilst the balance which covers the larger area, is a soft kaolinised rock containing quartz and sericite, probably an hydrated form of the first-mentioned rock.

There are also basic intrusions which consist of mica-hornblende-dolerite (diabase) that may possibly have influenced the enrichment of certain of the lodes. . . . . .

In the Ingliston Extended . . . . . , a basic dyke was encountered on the hanging wall side of the ore-body ; it is composed of a solid crystalline mica-hornblende-dolerite in the main mass, but adjoining the lode it has been considerably altered and sheared, and loses all crystalline structure.

In a Report on the State of Mining Progress in the Meekatharra and Peak Hill Goldfields, in 1909, the State Mining Engineer mentions the discovery of a large felsitic dyke in the Marmont, and a similar felsite dyke in the Ingliston Extended; and later, in the same Report, he notes the existence of a large intrusive dyke of hard greenstone, which has penetrated the lode and partly dislocated it.

Finally, in Bulletin 43, G.S., W.A., 1912, the present writer, as the result of a short visit to the mines of Meekatharra, published a preliminary account of the composition, structure, and relation of the chief rocks of the Ingliston Extended mine, and the evidence they afford as to the origin of the auriferous body, the peculiarities of its development and its probable life. Based, as this account necessarily was, on only a few specimens and on only a few days' work in the field, it was, of course, far from comprehensive or complete, but the detailed survey on which the present Bulletin is based, together with the examination of hundreds of specimens, has shown that the results then arrived at were, as far as they went, substantially correct. These results it is unnecessary to summarise, since the work on which they were based has all been revised in the light of the geology and petrology of the whole area.

It will be seen, therefore, that the petrological work hitherto carried out in the area has been but of a very casual nature, with results either of very doubtful or of merely local value. The present chapter marks the first attempt at a systematic and comprehensive investigation of the Petrology of the Area.

3.—CLASSIFICATION AND DESCRIPTION OF THE ROCKS.

The detailed classification of the rocks adopted is as follows :—

- I.—Acid Igneous Rocks
  - A.—Granites
  - B.—Porphyries
    - (*a*.) Paddy's Flat Dyke.
    - (*b*.) Yaloginda Group.
    - (*c*.) Maranui Group.
    - (*d*.) Commodore - Halcyon Group.
    - (*e*.) Romsey Group.
    - (*f*.) Pioneer Group.
    - (*g*.) Northern Ouctrop.
    - (*h*.) Doubtful weathered Dykes.
- II.—Basic Igneous Rocks
  - A.—Plutonic or Intrusive in Origin and not demonstrably volcanic—
    - 1. Comparatively Fresh Greenstones.
      - (*a*.) Ingliston Extended Dolerite.
      - (*b*.) Norite of Barloweerie Peaks.
      - (*c*.) Uralitised and Zoisitised Dolerites.
      - (*d*.) Epidotised Quartz-Dolerites.
      - (*e*.) Actinolitic - Zoisitic Rocks.
      - (*f*.) Fibrous - Zoisitic Amphibolites.
      - (*g*.) Fine-grained Dolerite of Meeka Hills.
      - (*h*.) Fine-grained Zoisitic Amphibolites.
      - (*i*.) Sheared Amphibolites or Hornblende Schists and Foliated dense-black Amphibolites.
      - (*j*.) Sheared Amphibolites and Epidiorites of Yaloginda.
      - (*k*.) Kyarra Schists.
      - (*l*.) Serpentines.
    - 2. Much altered Chloritic, Carbonated, Talcose Rocks
      - (*a*.) Flecked Schist.
      - (*b*.) Chloritic Slates.
      - (*c*.) Black Schists and Black Talc - Chlorite - Carbonate Rocks.
      - (*d*.) Flecked Chlorite - Carbonate Rocks.
      - (*e*.) Fuschite - Quartz - Carbonate Rocks.
  - B.—Volcanic or Eruptive in Origin.
    - Tuffs or Agglomerates, Crystal Tuffs, Basic Flows.
- III.—Sedimentary Rocks.

I.—Acid Igneous Rocks.

A.—*Granites.*

In a previous Bulletin,[1] Mr. Woodward, dealing with the Cue District, has made mention of two types of granite which are easily differentiated by their appearance in the field. According to him—

> The first type or what may be called hornblende granite, occupies about eighty per cent. of the total area covered by the acid series of rocks. It varies in its ferro-magnesian constituents with its relative position to the basic rocks; thus, in the proximity of these, hornblende and augite are in considerable evidence, while at a distance these minerals are often entirely replaced by biotite.
>
> The class of felspars met with in this granite so readily break down into kaolin that outcrops of rock in the fresh state are absolutely unknown, while frequently kaolinisation has been found to extend downwards to or below the permanent ground-water level, which may be as much as 150 feet below the present surface.
>
> The second type of granite is the hard porphyritic muscovite variety which generally occurs in the form of magmatic intrusions into the last mentioned. These intrusions are, as a rule, only exposed in areas of depression where they have been denuded by the removal of the enclosing rock. They mostly occur as extensive flats of rocks or more or less rounder bosses . . . . .
>
> From an economic standpoint these granites are of little interest, for, with the exception of a little wolfram and molybdenite, they are not mineral-bearing.

In the Meekatharra District, granite rocks, according to Mr. Clarke, occupy about 1,600 square miles of country. Owing, however, to the fact that they are of small economic importance, little attention has been paid to investigating the circumstances of their occurrence. Nevertheless, two types agreeing in the main with those already noted from the Cue District[2] have been recognised. For purposes of description, they are distinguished as—

1. The grey-green granite, or granodiorite;
2. The yellow granite.

1. *The grey-green granite.*

This type, as will be seen from the geological map of the area, runs in a general north-easterly direction, parallel to the prevailing strike of the different formations as a band three miles or more in width, and, except for a relatively small and ill-defined outcrop of type 2, comprises all the granite of the area dealt with in detail in this Bulletin. A continuation of the band to the south embraces the granite of Nannine. Except along the margin, this type forms in places rough breakaways, patches covered with rounded boulders, and only to a small extent (in contrast, as will be seen later, with the yellow granite), weathers on the surface into sheets or shells. The boundaries between it and the greenstones are generally ill-defined, both rocks being much decomposed along their margins. The granite, indeed, at the margin becomes a white mixture of kaolin and quartz, in which the only resemblance to the fresher rock is retained in the peculiar structure of the quartz plates. Only very rarely is a sharp contact visible.

1. G.S.W.A., Bull. No. 57, p. 20.

In the Nannine and Cue areas this granite contains a number of quartz reefs, which, in some cases, as in the Hidden Treasure Mine at Cue, are fairly strongly auriferous. At Quinn's somewhat auriferous reefs occur in what Gibson[1] calls granitic schists; and at Nannine[2] also reefs occur in the granite, though they appear to be of low grade.

At Meekatharra many quartz veins occur in this granite, but none appears to be auriferous.

In hand-specimens the work is generally of a gray-green colour, very coarse in grain, frequently with large, almost porphyritic, felspars. Specimens from different localities are at one time $\left[\frac{1}{129}\right]$ grayish-green with much green chlorite and numerous pale yellowish-white felspars, at another [**5354**] dark-gray and finer in grain, at another [**11210**] very coarse and light-grey in colour, while varieties have also been noted which are fine-grained with yellow epidotised felspars and small books of black biotite, or, as in $\left[\frac{1}{126}\right]$, dark-gray with pinkish felspars. There is thus a considerable degree of variation in the appearance of the specimens. Moreover, some of the rocks, *e.g.*, $\left[\frac{1}{129}\right]$ exhibit pronounced evidence of shearing that has resulted in an apparent foliation. Others, *e.g.*, $\left[\frac{1}{130}\right]$ show no trace of shearing. These characteristics indicate that if the whole is one rock mass, there has been a considerable degree of differentiation in the magma and a localisation of the dynamic strain along certain zones.

In section, the general coarseness of grain of the rocks is very apparent. The chief mineral constituents are:—felspar, quartz, the ferro-magnesians—chlorite, chloritic biotite and hornblende, epidote and zoisite, calcite, sphene and iron ore.

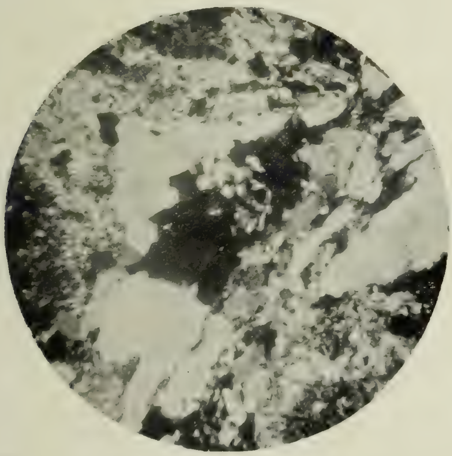
The felspars, generally in the form of large turbid plates, are by far the most common minerals in the slides. Though in rare instances, as in $\left[\frac{1}{130}\right]$, the crystals show an approach to define crystalline outlines, usually they are allotriomorphic, and in many cases there has been a partial granulation or crushing of the margins to form a coarse mosaic. The larger forms are in places epidotised and zoisitised, in places micacised with the production of muscovite in small scales; kaolin is not infrequently developed, and occasionally a small development of granular calcite has been noticed in them. The species present are, on account of the alterations the crystals have undergone, difficult to make out. There are commonly a plagioclase—in which the epidotisation and zoisitisation has taken place—crystals of an untwinned species referable, perhaps, to orthoclase,, and in nearly all sections large crystals of a species with the cross-hatched appearance of microcline more or less clearly shown. While this hatching seems in many cases to be of a primary character, it is probable, taking into account the large amount of dynamic strain the rocks have been subjected to, that it is in part a secondary character induced by this strain. In some

1. G.S.W.A., Bull. No. 14, p. 40.
2. Loc. cit., p. 56.

slides, crystals of an almost completely kaolinised form are enclosed in plates of an untwinned and little altered form, a fact indicating a tendency to a porphyritic structure in the rock. Kaolinisation has frequently attacked the interior of the crystals, while the margins are quite fresh. In some cases [11199] these are inclusions of quartz grains in microclinic plates, and of small quartz and kaolinised felspar plates in less altered felspar crystals; small cracks in some of the felspars are filled by quartz from the mozaic. Rarely there is a peculiar, imperfect development of a felspar inter-growth.

The quartz attains a much smaller development than the felspar. While there are sections showing the mineral in ragged plates of some size, most of it occurs interstitially between the felspar crystals in a highly granulated or crushed mass of small plates or grains (Fig. 74).

Fig. 74.



· Photo: R. A. F. Neg. 1229.

Microphotograph [$\frac{1}{131}$].—The hornblendic granite, showing the granulitisation of the quartz and felspar along lines between quartz and felspar plates.

Moreover, in most cases— [$\frac{1}{130}$] is a prominent exception— it is obvious that the force which has crushed the plates to a mosaic has also drawn out this mosaic so that it, with the chloritic strings which are frequently associated with it, wave round the felspars in indistinct "stream" or "flow" lines. These effects are undoubtedly due to crushing or shearing, and the green-and-white specimens of granite all show them to a pronounced extent. So common are they, that there would appear to have been a grinding of the felspar plates over one another with complete crushing of the interstitial quartz, especially as it has already been noted that many of

the felspars show granulated margins. These phenomena are particularly noticeable in [11316] and $\left[\frac{1}{129}\right]$. In $\left[\frac{1}{128}\right]$, on the other hand, the large flaky quartz has been only slightly granulated.

In $\left[\frac{1}{130}\right]$, where granulation has not taken place, the interstitial character of the quartz is very noticeable, since the felspars have an almost idiomorphic outline.

The ferro-magnesians occur only very sparingly, though such specimens as $\left[\frac{1}{129}\right]$ and $\left[\frac{1}{131}\right]$ have a decided greenish tinge. The commonest are a green chlorite, sometimes in isolated flakes and flaky aggregates or patches, but generally in thin strings associated with the quartzose mosaic, and in strings round the felspar crystals, and a green pleochroic chloritic biotite in isolated flakes and, in [5354], also in strings in the granular mosaic. The chlorite and chloritic biotite are frequently associated with yellow-green epidote grains, less commonly with granular calcite and grains of sphene. In $\left[\frac{1}{130}\right]$ there are occasional large ragged flakes of a brown pleochroic biotite, while in $\left[\frac{1}{128}\right]$ there are large dark-green flaky patches of pleochroic chlorite. In $\left[\frac{1}{131}\right]$, occur some obscure large forms consisting of chlorite flakes, calcite and epidote grains and minute flakes of quartz, which may be the altered remains of pre-existing hornblende. Fresh hornblende in the rocks examined is rare, but in $\left[\frac{1}{128}\right]$ it occurs in large fragments of a deep green colour with a pleochroism in green and yellow tones. Some of the chlorite flakes also undoubtedly possess a character suggesting a derivation from hornblende.

Of the remaining constituents, epidote is easily the most common, and in some sections, *e.g.*, of $\left[\frac{1}{130}\right]$, it is so common in the felspars as to impart a yellow-green tint to them. It is associated also with both the chlorite and the chloritic biotite flakes and at times occurs as large pistachio-green grains by itself. Zoisite grains are developed occasionally in the plagioclase felspar. Sphene granules and calcite grains are visible in small amount with the chlorite, though the calcite as already remarked, appears in some of the felspars.

The structure of the rocks is, in almost all cases, platy and granular, an approach to a porphyritic character being only rarely noticeable. In most of the slides, however, there is evidence of considerable mechanical deformation or crushing and shearing. This is afforded by the extreme granulation of the interstitial quartz—and, to a small extent, of the felspar—the granulation of the margins of some of the large felspars, bending and cracking of both the quartz and felspar plates, drawing out of the chlorite scales in strings, and very pronounced irregular extinction in the colourless constituents. This crushing and shearing has, in some cases, *e.g.*, [11199], [5354] $\left[\frac{1}{129}\right]$, produced an incipient though imperfect foliation or banding, in which there are thin stringy folia

of chlorite scales separating imperfect bands or lenticles of quartz mosaic and sheared felspars. An approach to a gneissose structure has thus resulted in some of the rocks. The mechanical deformation is well illustrated in [**11316**] and $\left[\frac{1}{129}\right]$[1].

2. *The Yellow Granite.*

This granite occupies but a very small area in the Meekatharra Field (Plate IV., sheet B). It outcrops west and south of Yaloginda, being typically developed near the Chunder Loo Mine, where it is seen as rounded boss-like masses of some size and height. It was noted as far north as the 17-mile post on the Telegraph Line beyond which the boundary between the granite and the greenstones becomes obscured, and some distance north of the Meekatharra Creek, the gray-green type is found. Owing to there being little of economic value associated with the various outcrops, it was inadvisable to devote more time to an examination of them than was necessary to collect a few specimens, and consequently none of the outcrops has been accurately mapped.

According to Mr. Woodward, this "yellow granite" is identical with his second type, the hard porphyritic muscovite granite previously referred to. Like the latter, it occurs in rounded hummocky forms which, from the expansion and contraction due to the considerable extremes of heat and cold in this latitude, weather in a manner recalling the spheroidal weathering of some dolerites. Sheets or shells crack off often with a loud report exposing a fresher spheroidal surface which in turn is similarly shed.[2]

In general appearance, the rock is a medium-grained granite of yellowish colour consisting of quartz and felspar in almost equal proportion with scattered groups of fine scales of blackish biotite and scales of yellow muscovite. Frequently there are coarse and fine microcline pegmatitic varieties. While, in the mass, the rock is massive, at and near the margins there is often an incipient foliation developed, a phenomenon which has already been remarked in the granite from Southern Cross. There are further noteworthy resemblances between the "Yellow Granite" and the latter, both in colour and mineral composition.

In section, the massive rock consists of large allotriomorphic plates of felspar and quartz with areas in which the quartz and felspar plates appear to have been partially granulated or broken down into an indistinct mosaic, and occasional flakes of brown pleochroic biotite. The species of felspar include microcline (which forms the largest crystals), untwinned forms that may be orthoclase or microcline, and a finely twinned plagioclase which is sometimes kaolinised in the middle or less commonly micacised.

1. In composition, therefore, this grey-green granite approximates closely a quartz-diorite.
2. *Vide* G.S.W.A., Bulletin 57, p. 25, *eet. qs.*

Much, though not all, of the felspar is turbid, and, enclosed in the microcline plates are sometimes small grains of quartz. In the partially granulated areas, a vermicular micropegmatite is quite common. Muscovite flakes are rare, and their occurrence generally associated with turbid felspar suggests that they are alteration products of the latter, though a few flakes are to be seen unconnected with felspar. Biotite is the dominant mica. A few grains of epidote occur sporadically. Both the quartz and the felspar are not without cracks, and irregular extinction is exhibited by both, though to a small extent only.

The foliated variety in section presents an appearance strikingly similar to [**11199**], [**5354**] and [$\frac{1}{129}$] in the incipiently foliated structure produced by strings of brown biotite and brown biotitic chlorite flakes or scales generally accompanying bands of granulated quartz and felspar mosaic, which curve round platy crystals of felspar that in places have broken and granulated margins. There are, however, distinct lenticular bands of quartz more or less broken down into small plates. In certain spots, the rock is almost a granulitic biotite gneiss with strings of biotite scales separating clear bands of granulitic quartz and felspar, though the strings can be seen curving round large platy crystals of felspar that have still remained. As in the massive varieties, there is vermicular micro-pegmatite; there are crystals with indistinct microcline structure, but there is much irregular extinction, there are numerous cracks and a general appearance closely approaching that in [**5354**], [**11199**] and [$\frac{1}{129}$]. There is no doubt that the foliation has been caused by dynamic strain, though there may have been—as suggested by the discontinuous yet homogeneous quartz lenticles—some amount of original banding.

Relation between the Two Types:

The question arises as to what is the relation between the Grey-Green Granite or Granodiorite and the Yellow Granite. Generally speaking, in hand specimens they are unlike. While the former, represented by [$\frac{1}{121}$], has pale yellowish-white felspar in excess of quartz associated with dark green chlorite, and more or less epidotisation of the felspars as well as a considerable amount of yellow epidote enclosed by chlorite, the latter is characterised by yellowish-white felspar with an equal development of quartz, and scattered scales of brown biotite. Moreover, in the field it is to be observed that while pegmatitic microcline veins are common as offshoots from the Yellow Type, occurring often as thin dykes intruded parallel to the schist planes of the greenstones, they have not been observed arising from the Grey-Green Type. On the other hand, the quartz veins which frequently occur in the latter, have not been found in the former. The junction between the yellow granite and the greenstones is rarely much weathered, both rocks appear to become

harder as the junction is approached, and in places, according to Mr. Clarke, small lenticles of greenstone are found in the granite even some distance from its margin. Further, from the descriptions given above, it is clear that while Type (1) the grey-green granite is generally sheared and dynamically strained, there are specimens, notably $\left[\frac{1}{130}\right]$ which are unsheared, and in Type (2), while most of the rock is massive, there are undoubted portions (probably the margins) which show evidence of much dynamic strain. Again, while the difference in the colour of the rocks and their constituents is marked, there are specimens of Type (1), *e.g.* [**11199**] possessing much pinkish felspar, and specimens, *e.g.*, $\left[\frac{1}{126}\right]$ which, while similar to [**11199**] in the rock mass, nevertheless on the weathered surfaces show a distinct resemblance to Type (2).

In mineral composition there is a resemblance between such specimens as [**11199**] and $\left[\frac{1}{126}\right]$ of Type (1), and the Yellow Granite, mainly in the species of felspar present, and between [**11199**] and [**5354**] on the one hand, and the foliated variety of Type (2) on the other, both in structure, effects of deformation, and apparently in the species of felspar present in both. On the other hand, green chlorite and hornblende and highly epidotised felspars are peculiar to Type (1).

For the Cue District, Mr. Woodward is definite about the relation of the two types. Writing of the "Hard porphyritic muscovite variety," he states:—

> This type of granite is evidently of more recent origin than the hornblende variety into which it has, as previously stated, been intruded in the form of either magmas or dykes, which are exposed in the form of sheets, bosses, or dykes after the latter class of rock has been removed by erosion. . . . . . [1]

In the Meekatharra area, however, the evidence at present in hand is not sufficient to be conclusive. Undoubtedly in the case of the type specimens there are marked differences and the peculiar boss-shaped outcrops suggest a later age for the Yellow Granite; But the occurrence of what from their structure and composition appear to be intermediate varieties presents difficulties which can only be cleared up by accurate mapping of the outcrops and the examination of a suite of specimens.

B.—*Porphyries.*

A remarkable feature of many of the porphyries of the area is the fact that they do not outcrop at the surface. Even underground in the mines, in many cases they are so weathered that it is only with extreme difficulty they can be identified and traced, and not infrequently their presence can be only inferred from the character of the kaolinic decomposition products. Such a well-marked

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1. Bulletin 57, p. 29, *et. seq.*

geological feature as the Paddy's Flat porphyry, for example, would, from surface indications, never be suspected, though below 300ft. it is generally a beautifully fresh, hard rock, fairly constant in petrographical character through a series of mines. In the Hornsby, the Beverley, and two or three other groups of workings, no fresh porphyry could anywhere be discovered, and determination of its former presence has depended on relics of original structure and composition preserved in white, yellow or red-stained clays. Moreover, careful study has shown that there is a considerable degree of variation both in mineral composition and structure in the various occurrences. They are found mostly in isolated spots, often with no connection between them traceable in the field, either on the surface or underground; and, owing to the advanced decomposition of the majority of the rocks in the area, their field relations to other types are usually obscure.

When, therefore, attempts were made both to delimit the boundaries of those dykes and to correlate the specimens from different localities with the object of tracing probably continuous dykes, much difficulty was experienced. In default of definite evidence of connections from field work—which was frequently unobtainable—recourse was had perforce to evidence afforded by such characters as structure, composition, and strike, and by a comparison of the products of alteration in the rocks in the various mines. While the limitations of these criteria were fully recognised, results have been obtained which, it is claimed, are as accurate as the circumstances of the investigation will allow.

Classification.—From the point of view of mineral composition and structure, the rocks may be grouped in the following divisions:

(a) Albite porphyries without quartz;
(b) Albite porphyries with quartz;
(c) Granitic porphyries;
(d) Albite porphyries with chloritic and actinolitic needles and nests;
(e) Chloritic albite porphyries with chlorite in small scales;
(f.) Felsitic quartz porphyries;
(g) Hornblende-quartz porphyry or porphyrite.

While, however, all these divisions are recognisable, it has been found that, in spite of the differences, there are very strong similarities between specimens from different localities, there are considerable variations both in structure and mineral composition in the same dyke, and not only are the dykes themselves mostly located in distinct mine-groups, but generally more than one of the above divisions are developed in any group of leases. For clearness and convenience, therefore, in the treatment of the rocks, as well as on account of the increased ease with which the distribution of the rocks and, consequently, of the auriferous formations can be grasped, it

has been considered more desirable to classify these porphyries on a basis of mine-groups. They will, therefore, be described under the following heads:—

(a) Paddy's Flat Dyke;
(b) The Yaloginda Group of Dykes;
(c) The Maranui Dyke;
(d) The Commodore-Halcyon Dyke;
(e) The Romsey Dyke;
(f) The Pioneer Dyke;
(g) The Northern outcrops;
(h) Doubtful, much weathered Dykes.

The distribution and boundaries of the rocks arrived at by a co-ordination of both field and microscopic work will be found on Plate IV., Sheet B.

(a) *The Paddy's Flat Dyke.*

This, the most important of the porphyry dykes of the Area, runs through the Paddy's Flat Belt in a general north-easterly direction almost continuously from the Gwalia Extended group of leases at the south end of the Paddy's Flat Belt to the Ingliston North G.M.L. Owing to the facility with which it decomposes to a white kaolin, and to the thick covering of lateritic material on the surface, it has never been found outcropping, but in the mine-workings, especially at the lower levels, it forms an almost continuous dyke. Where fresh it is of a semi-translucent white colour, is hard and flinty, and so fine-grained that, were it not for occasional reflecting surfaces of felspar crystals, it would easily be mistaken for quartz or quartzite. Only careful search reveals the presence of small white phenocrysts of felspar and, occasionally, of quartz, though veinlets of quartz and sometimes films or incrustations of crystalline carbonate are sometimes to be seen in it. There is an entire absence of ferro-magnesians and, in the freshest specimens, even of muscovite. Grains and small crystals of pyrites and, more rarely, of arseno-pyrite are, however, generally to be found. In the mass, a blocky structure due to cross-jointing frequently appears.

The rock is prone to decomposition, and, as a result, its colour undergoes considerable change. In some specimens, while part of the rock is still white and fresh, part, owing to the production of much whitish muscovite or paragonite has taken on a pale yellow tint. Other specimens are wholly altered to the micaceous material except for blebs of white quartz; others, similarly altered, have become dark grayish-yellow in tint, though still retaining a semi-translucency. In some varieties quartz veinlets are absent, in others, quartz veins are common and thick, and in others, portion of the rock consists entirely of quartz. In rarer cases, very quartzose portions are penetrated by veinlets of white crystalline carbonate.

In section the rock is composed of irregularly-outlined phenocrysts of felspar and somewhat rare phenocrysts of quartz in a ground-mass of irregular felspar plates and laths of extremely varied outline; a little quartz in small grains is interspersed amongst the felspar. The felspar phenocrysts are generally more or less tabular or columnar, frequently kaolinised and micacised. Quartz phenocrysts are rare, but when present, are rounded, squarish, or irregular in outline, sometimes granulated at the margins and at times embayed by the ground-mass. The latter is mostly fine-grained, with little plates, rods or laths of felspar far in excess of the small grains of quartz. In some specimens quartz is almost entirely absent (Fig. 75). Most commonly, there is no trace of ferro-magnesians, but rarely a flake of greenish chlorite is visible in section, and on a few specimens there is a crust of green chloritic scales and carbonate plates.

Fig. 75.

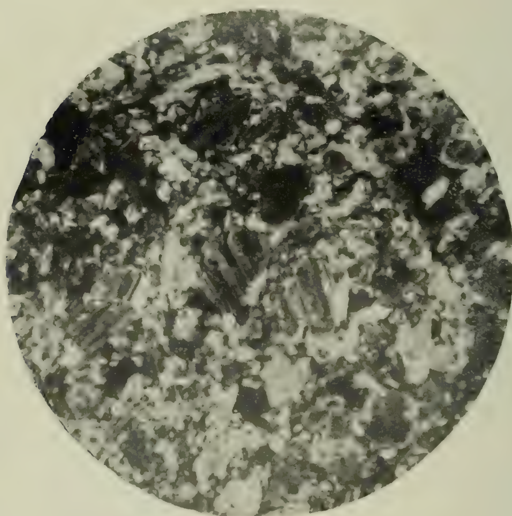


Photo: R. A. F. Neg. 1235.

Microphotograph [$\frac{1}{96}$].—Showing a mass of small platy felspar crystals.

In the yellowish specimens, the felspar has been almost wholly replaced by white mica scales in strings and aggregates. The species of felspar present, owing to the kaolinisation and to paucity of crystals showing clear lamellation, was difficult to determine, but in those cases where observations of the extinctive angles on symmetrical albite twins could be made, it appeared to be albite. A chemical

analysis of an average specimen of the fresh rock [$\frac{1}{90}$] performed in the Survey Laboratory confirmed this identification and gave these results:—

	I.		II.
SiO_2	77·78		77·66
Al_2O_3	11·87		12·30
Fe_2O_3	·49		·61
FeO	·32		·17
MgO	·40		·73
CaO	·50		·16
K_2O	·18		·19
Na_2O	6·82		6·96
Fe	·29	·85*	..
As	·39		
S	·17		
Fe	·16	·34†	..
S_2	·18		
Ignition Loss	·59		·46
Total	100·14		99·24

I. Specimen [$\frac{1}{90}$]: Fenian G.M., Level No. 5. Analyst, H. Bowley.
II. Quartz keratophyre: Navigation Creek, Noyang District, Omeo, Victoria, Australia.

It will be at once evident that the rock is extremely acid, and that practically the whole of the felspar is albite. The small amounts of CaO, MgO, and FeO are accounted for by the presence of chloritic scales and carbonate crystals occurring as a crust on the specimen analysed.

The Paddy's Flat dyke, therefore, is an albite-porphyry with or without quartz phenocrysts. Its remarkable resemblance to the Quartz-keratophyre from Omeo, Victoria, is shown by Analysis II., quoted for comparison.

(b) *The Yaloginda Group of Dykes.*

There are outcrops of porphyry—frequently as hillocks—at intervals from the neighbourhood of the Sirdar Group to the southern boundary of the Area, a distance of nearly five miles. Though these exhibit sundry minor differences, both for convenience in description and on account of remarkable similarities between them, these have all been grouped under the title of the Yaloginda Dyke.

The most northerly outcrop is just west of the Sirdar Group. The rock represented by **47d** [$\frac{1}{874}$] is fine-grained, white and fresh, with some micaceous scales. In section, there are numerous small, irregularly outlined but mostly rounded or stumpy columnar phenocrysts of slightly kaolinised felspar, and rather rare rounded phenocrysts of clear quartz in a fine-grained ground-mass made up

* Represents arsenopyrite.
† Represents pyrite.

almost wholly of ragged plates and occasional stumpy laths of felspar, with infrequent quartz plates and with strings and scattered scales of white mica. The felspar is almost wholly albite.

This rock, in external appearance, in mineral composition and structure, is almost identical with the Paddy's Flat albite porphyry.

Some distance to the south of this, about 20 chains north-west of the N.W. peg of the Black Jack Group, there appears an outcrop of a somewhat weathered, dull, creamy-white, fine-grained, highly felspathic rock, with minute specks of a dark-green, at times of a light-green colour, in the white mass. Sections from typical specimens, *e.g.* $[\frac{1}{108}]$ show the rock to consist largely of ragged phenocrysts of a cloudy kaolinised felspar in a granular ground-mass composed almost wholly of felspar in small ragged laths and plates. Quartz is absent from among the phenocrysts, nor was it observed in the ground-mass. At intervals through the latter are small nests or bundles of fibres of a dirty-yellow tint. Owing to the minuteness of the needles and the dense nature of the bundles, it was impossible to definitely determine the mineral. In some respects, its characters were micaceous, in others, those of minutely acicular actinolitic or tremolitic inclusions in quartz and felspar. In places the needles traverse the felspar phenocrysts. The rock is highly felspathic, though the species of felspar were not determinable.

In shaft 25, Kelpy Group, a little to the north of the above, there outcrops a fine-grained white porphyry $[\frac{1}{109}]$, which in colour and granularity has the external appearance of beet-sugar, and which exhibits greenish chloritic material along cracks. In section, the rock proves to be an albite porphyry with ragged columnar and platy phenocrysts of slightly clouded felspar in a ground-mass of felspar in small grains and less common ragged laths. All the crystals are ragged, and the phenocrysts show, frequently, bent lamellation, cracks, faults, and irregular extinction as evidence of dynamic strain. The porphyritic character is not well characterised. An analysis of this rock in the Survey Laboratory gave the following results:—

SiO_2	68.19
Al_2O_3	19.47
Fe_2O_3	.08
FeO	.24
CaO	.21
MgO	.13
K_2O	.06
Na_2O	11.60
Ignition Loss	.26
Total	100.24

Analyst, H. Bowley.

The remarkable feature of this analysis is the extremely high percentage of soda, proving, with the almost complete absence of potash, that the felspar is wholly albite. Since $[\frac{1}{108}]$ closely resembles $[\frac{1}{109}]$ though $[\frac{1}{109}]$ is without the acicular wisps and needles, both must be put down as albite porphyries, and though their structure differs slightly from that of the Paddy's Flat dyke there is little doubt they are genetically connected with it.

Finally, at the most southern end of the Area, about a quarter-mile west of the 324½-M.P., on the Railway line, and again about three chains west of this point, a fine-grained felsitic porphyry dyke has been found outcropping. The outcrop at the former position, represented by $[\frac{1}{118}]$ is a dark-grey, minutely-grained flinty rock, resembling on the fresh surfaces some varieties of flinty quartzites. On weathering, the rock becomes yellowish-white. A section of this type shows a few rounded quartz phenocrysts, and small ragged, columnar and platy, partially kaolinised felspar phenocrysts in a fine-grained platy ground-mass composed mostly of polygonal granules of felspar and some quartz, and with grains of calcite, flakes and small strings of colourless muscovite, and rare scales of green chlorite scattered through the mass. A peculiarity of the rock is the presence of rounded aggregates of plates of a minute felspathic intergrowth, of rounded plates of felspar with a radial structure, and of a coarse quartz-felspar intergrowth.

The outcrop somewhat west of this, $[\frac{1}{119}]$, is a dull, pinkish extremely fine-grained felsitic rock, with quartz veinlets and with some felspar crystal visible to the naked eye. In section, it is seen to be patchy. Some patches are microcrystalline, others are composed of a fairly coarse mosaic of kaolinised felspar and quartz plates. The rock shows a distinct approach to the granophyric structure, quartz and felspar intergrowths making up much of the mass. In fact, except for the rare cloudy phenocrysts, almost the whole of the felspar is contained in a quartz-felspar intergrowth often so fine as to be distinguishable only with difficulty. An occasional patch of quartz mosaic occurs in places as well as a few scales of yellowish chlorite.

Both these outcrops, therefore, are of felsitic quartz pophyry, but whether they are but varieties of the same rock mass is difficult to state. Both in hand specimens and in structure $[\frac{1}{119}]$ differs from $[\frac{1}{118}]$ but, since, owing to the fineness of grain of $[\frac{1}{118}]$ and the kaolinised condition of the felspar in $[\frac{1}{119}]$, it was impossible to determine the species of felspar, since there are no analyses at hand to indicate whether potash or soda is predominant in them, and since it was impossible to determine their relation in the field to one another, to other porphyries, or to granitic masses, or even to the surrounding rocks, their affinities must for the present remain

obscure. The felspar of $[\frac{1}{119}]$ would appear not to be albite but either orthoclase or microcline. On the other hand, $[\frac{1}{118}]$, bears some resemblance to varieties both of the Paddy's Flat and of the Maranui dyke, so that $[\frac{1}{119}]$ may be a dyke genetically different from the albite porphyries of the field.

The Maranui Dyke.

This outcrops about a quarter of a mile east of the Karangahaki Belt and has been followed for about a quarter of a mile in a southerly direction. Beyond this, it is lost sight of, but boulders of tourmaline-bearing quartz may indicate its extension towards Rhen's prospecting area. The outcrop varies somewhat in external appearance, but the chief characters are represented in $[\frac{1}{104}]$ and $[\frac{1}{105}]$. The former $[\frac{1}{104}]$, from about eight chains north of the north end of the Maranui (G.M.L. 899N) is a semi-translucent felsitic flinty rock with occasional phenocrysts of felspar and some minute veinlets of quartz and pin-heads of yellow micaceous and of soft greenish talcose material. In section there are occasional large highly kaolinised phenocrysts of felspar, and rarely a rounded phenocryst of quartz in a fine-grained ground-mass, consisting of shapeless small plates and short thin ragged laths of felspar and grains of quartz, though the latter, on account of the fineness of grain, is difficult to determine. Numerous minute veinlets of quartz and of quartz and felspar plates traverse the slides, and in the ground are small radiated nests of yellow-stained fibres that resemble at times chloritised actinolite needles, at times altered micaceous wisps. In addition, in the ground are small scaly patches of a mixture of talc and chlorite scales and some calcite grains. Felspar is predominant and the species is albite.

$[\frac{1}{105}]$ differs from $[\frac{1}{104}]$ in being dark-grey in colour, with a weathered red crust and with phenocrysts of quartz and felspar easily distinguishable. The ground-mass closely resembles that of the dark-grey micacised varieties of the Paddy's Flat dyke.

In section, there are large highly kaolinised phenocrysts of striped felspar and fewer of quartz in a holocrystalline ground-mass of quartz grains and irregular plates and laths of felspar. Throughout the mass are small flakes and strings of colourless mica. While the phenocrysts have not been micacised, they frequently, however, enclose granular calcite. Occasionally, there appear small green scales and elongated columnar scaly aggregates of greenish chlorite with associated calcite, which are probably pseudomorphs after a a ferro-magnesian.

Though the species of felspar in $[\frac{1}{105}]$ could not be made out accurately, there is little doubt that, as in $[\frac{1}{104}]$, it is predominantly albite. These two specimens, therefore, which are put down as albite-quartz-porphyries, may be regarded as but varieties of the

same dyke mass. They are undoubtedly so in the field. Moreover, both in appearance and in structure and mineral composition they closely resemble the varieties of the Paddy's Flat porphyry and are probably genetically connected with it.

(d) *The Commodore-Halcyon Dyke.*

In the Commodore and Halcyon Groups specimens have in places been obtained of rocks which, while varying in appearance within wide limits, are nevertheless characterised by fairly constant and peculiar microscopic characters. Typical specimens are **345c** $[\frac{1}{321}]$ and **346c** $[\frac{1}{875}]$ from the Commodore North, crosscut east, 107ft. level, about 200 feet from shaft L; **73d** $[\frac{1}{876}]$ from the Commodore North dump (shaft I); $[\frac{1}{101}]$ from the Commodore G.M., No. 3 level, near the north end of drive on East lode; and $[\frac{1}{308}]$ from the Halcyon Extended G.M.L., 160ft. level, south end (near shaft H).

In hand specimens, these vary from dark, grey-green rocks such as $[\frac{1}{308}]$ showing numerous reflecting surfaces of felspar in a dark-greenish chloritic mass with numerous crystals of pyrites, to weathered forms like **73d.** $[\frac{1}{876}]$, in which the characters of $[\frac{1}{308}]$ are obscured by yellow alteration products such as granular limonite and yellow-stained chlorite.

In section, **346c** $[\frac{1}{875}]$ is a comparatively fine-grained rock consisting entirely of ragged, irregular laths or small columns of irregularly twinned felspar with an equal development of small plates of the same mineral distributed between the laths and columns. Rarely some columnar and rounded felspar crystals are larger than the others. There is no trace of ferro-magnesian, except perhaps in minute needles now of oxidised iron ore.

In **73d** $[\frac{1}{876}]$, of which specimens are considerably decomposed and of a yellow colour due to earthy limonite, there are coarse plates and columns of felspar with numerous small nests of yellow chloritic scales associated with brownish dusty iron ore. The felspars examined proved to be either albite or near andesine. In some sections, remnants of columnar ferro-magnesian forms, possibly hornblende, occur, as well as occasional apatite needles.

In $[\frac{1}{101}]$ there is a fine-grained loose plexus of rather ragged laths of felspar in the numerous yellow-green chlorite scales, and scaly patches. Sections closely resemble those of $[\frac{1}{876}]$, but the felspars, instead of being, as in $[\frac{1}{876}]$, in large platy and columnar forms, are in a fine-grained plexus. A small amount of quartz in minute plates appears in places.

345c $[\frac{1}{321}]$ differs considerably from these rocks. Sections show many large yellowish-brown columnar and platy forms of a chloritised ferro-magnesian separated by large platy and columnar

crystals of a slightly kaolinised felspar with occasional large apatite needles. The ferro-magnesian, from the shape of the longitudinal and cross-sections as well as from measurements of the prism angles was undoubtedly hornblende. The felspar is difficult to determine owing to the indefiniteness of the twinning, but appears in at least one instance to be albite. A peculiarity of the mineral is that many of the plates scarcely exhibit twinning and resemble platy orthoclase; others have an indefinite broad lamellation; some are micacised.

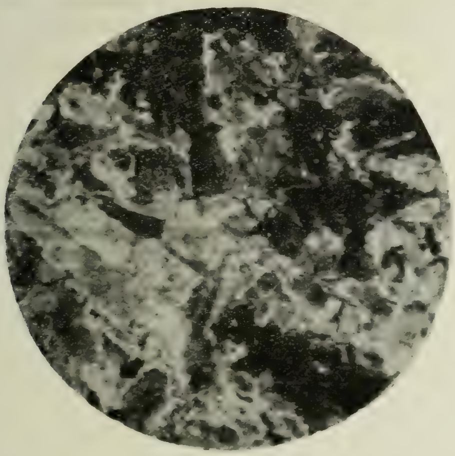
The affinities of this rock are not clear. Certainly, from the field evidence, it is of the same rock mass as $\left[\frac{1}{875}\right]$, the former being from the margin of the mass, and the latter from well inside the margin. On the other hand, as will be seen by reference to the Greenstone Division, there is, allowing for the alteration by weathering in **345c** $\left[\frac{1}{321}\right]$, a resemblance between it and $\left[\frac{1}{306}\right]$ which is undoubtedly a fresh greenstone of syenitic or dioritic character. The weathered nature, however, of the specimen, together with the fact that, owing to the limited extent of the workings, it was possible to obtain the rock only in one spot, render it impossible for the present to state whether it is a marginal facies of $\left[\frac{1}{875}\right]$ or, if not, what its genetic relationships really are.

With the possible exception, then, of **345c** $\left[\frac{1}{321}\right]$ the rocks of these mines are all very similar both in composition and structure. They all consist of plates and laths of irregularly twinned felspars forming a coarse or fine plexus and all fairly fresh, with associated greenish and yellowish-green or yellow scales and scaly aggregates of chlorite with more or less apatite in minute needles. In every case, with the above exception, the felspar appears to be albite, and in nearly every case, there is in the rocks a strong development of pyrites in small crystals. The rocks are all apparently chloritic albite porphyries.

This peculiar facies is not, however, confined to the Commodore and Halcyon groups. About 15 chains west of the N.W. peg of Black Jack (G.M.L. 834N), *i.e.*, about 5 chains to the south-east of $\left[\frac{1}{108}\right]$ which is similar to the Paddy's Flat dyke, there is an outcrop of a fine-grained, dark, grey-green rock $\left[\frac{1}{291}\right]$ which consists on the fresh surface of pale yellowish-grey felspathic material interspersed with small dark-green chloritic patches. At first sight, the rock resembles many felspathic greenstones, but, in section, it appears as a mass of large, platy and numerous small columnar or broad lath-shaped felspar crystals forming a coarse plexus of plates and columns. The outline of all the forms is ragged and uneven, while, in the mass, are occasional scales, scaly aggregates and small strings of pale yellowish-green chlorite and a few grains of black iron ore. Felspar forms the bulk of the rock, the chlorite being relatively small in amount (Fig. 76).

This outcrop is therefore strikingly similar to such chloritic albite porphyries as $\left[\frac{1}{876}\right]$ From field evidence it has been mapped as an offshoot of the Yaloginda Dyke.

Fig. 76.



• Photo: R. A. F. Neg. 1237.

Microphotograph $\left[\frac{1}{211}\right]$.—The section consists wholly of platy and ragged columnar felspars with scattered scales of green chlorite.

Again, in other specimens from the Commodore, *e.g.* $\left[\frac{1}{356}\right]$ from the Commodore No. 3 Level, north end of drive on East Lode, a very considerable amount of contortion has taken place and there is, moreover, a small development of a green micaceous mineral referred to fuchsite. The plexus of ragged laths of felspar, however, still persists.

(e) *The Romsey Dyke.*

In the Romsey Group, rocks have been encountered underground which show the remarkable similarities to those occurring in the Commodore-Halcyon Dyke. These are respresented by $\left[\frac{1}{106}\right]$ and $\left[\frac{1}{107}\right]$ from Morris' P.A., at the north end of the Romsey (G.M.L. 891N); $\left[\frac{1}{\ }\right]$ from the Romsey G.M.L., main shaft, bottom level, north-south end; and $\left[\frac{1}{339}\right]$ from Romsey shaft 3, bottom level.

$\left[\frac{1}{107}\right]$ is a much altered, brownish-yellow, fine-grained rock with several small parallel broken quartz veinlets, apparently filling cracks or joints. There is another series of cracks without quartz, nearly at right angles to the veinlets and seemingly faulting the latter. Some oxidised pyrite crystals occur in places.

In section, alteration is pronounced in the rock and there is much yellow staining. There are numerous small lath-shaped and thin prismatic crystals of a highly lamellated felspar with some small round grains of quartz and numerous grains apparently of limonite. There is much yellow chlorite in veins and in scattered scales. Decomposition has greatly obscured the character of the rock but it appears to be a fine-grained felspathic plexal chloritic porphyry.

$\left[\frac{1}{111}\right]$ is an altered albite porphyry with quartz veinlets and yellow chloritic scales essentially similar to $\left[\frac{1}{101}\right]$ and $\left[\frac{1}{107}\right]$.

$\left[\frac{1}{339}\right]$ on the other hand, presents an exceptional appearance. This is a sheared dark green very fine-grained chloritic rock with quartz veinlets along which there has been a considerable amount of bleaching of the chlorite with the production of a reddish margin on both sides of the vein, and in places where the quartz stringers have penetrated along the shear planes. The rock resembles a fine-grained sheared chloritic greenstone.

Under the microscope, however, it is found in some sections to consist of a mass of numerous small very ragged laths of irregularly twinned felspar and small plates forming a very loose plexus. The twinning in many of the laths gives rise to a structure with an appearance like that of rods (the lamellae) diverging from a common centre; the lamellae, also, are often slightly curved. All over the felspar plexus are small greenish scales and strings of a chlorite with occasionally associated small black grains, greyish by incident light and hence perhaps leucoxene. Granular aggregates and grains of a carbonate are not infrequent in the sections.

Other sections of this rock, parallel to the shearing, curiously enough, show a different structure. In these, there are a few columnar kaolinised phenocrysts of felspar and more numerous small lath-shaped phenocrysts of felspar in a very minutely grained ground mass apparently of felspar and scales of pale green chlorite. There is a suggestion of parallel alignment of the felspar laths which may be due to shearing or may be a primary flow structure. Very indistinctly, in places in the ground-mass, are visible traces of a plexal character resembling that in the previous sections. The character of the felspar is again undeterminable with certainty, but appears to be albite.

From the resemblance of the rock in some slides to $\left[\frac{1}{107}\right]$ and $\left[\frac{1}{111}\right]$ in conjunction with the porphyritic mixture, it would appear to be again a chloritic albite porphyry, though further specimens and more information as to its field relations—at present quite unobtainable—are desirable before its affinities emerge from obscurity.

(f) *The Pioneer Group.*

Just east of Meekatharra in the Pioneer Group of leases, acid porphyries have been discovered. The Group includes Savage's

(93N), the Pioneer Continuation, the Pioneer West, and the Sweetheart. In the latter, the rock is in a state of decomposition too advanced for any microscopic examination, but the kaolinic remains leave little doubt that the original was a porphyry similar to those in the other leases. The only outcrop of the rock occurs in the Pioneer West, the specimens from Savage's and the Pioneer Continuation being obtained from the mine workings.

The rock from Savage's (93N) is represented by $[\frac{1}{102}]$. This is a granitic porphyry, yellowish-gray in colour, of rather fine grain, with crystals of quartz easily visible in a pale-yellowish felspathic mass, or with occasional quartz veinlets.

In section, there are large ragged rectangular and tabular crystals of felspar and fewer rounded and ragged crystals of quartz in a coarse platy ground-mass of quartz and felspar plates, through which run strings of muscovite. Many of the felspar plates appear in process of breaking down into grains, and all are more or less micacised and slightly kaolinised. The species present are difficult to determine, but untwinned plates are probably orthoclase, while there is a considerable amount of an acid plagioclase. The large felspar crystals are mostly platy, euhedral forms being rare, so that porphyritic structure is very indefinite. The lack of definition is heightened by the coarseness and indistinctness of the ground-mass and the breaking down of the larger plates. Indeed, from the ragged character of the minerals, the slides show a considerable resemblance to certain arkoses.

A typical representative from the Pioneer Continuation is $[\frac{1}{91}]$. In hand-specimens, this is a yellowish-gray, blocky, highly felspathic granitic rock of medium-grain and with occasional quartz-veins and flattened biotite nests. In section there is a strong resemblance both in composition and structure between it and $[\frac{1}{102}]$. There are large tabular and columnar crystals of slightly micacised and kaolinised, broadly lamellated felspar and fewer somewhat ragged plates and squarish crystals of quartz in an indistinct ground-mass of small felspar and quartz plates, with yellowish flakes of muscovite and yellow-brown—in places greenish—chloritic biotite flakes occurring sporadically. As in $[\frac{1}{102}]$, both the felspar and quartz crystals are in process of breaking down to small grains. The ground-mass is very small in amount, and owing to the number of quartz and felspar plates intermediate in size between the small grains and the larger crystals, very indistinct. There is again a resemblance in the ground-mass to a quartz-felspar cement, and this with the ragged character of many of the larged crystals gives a clastic appearance to the structure of the rock. Porphyritic character is indefinite.

The only surface outcrop in the group occurs in the Pioneer West, and of this **72d** $[\frac{1}{877}]$ is fairly typical.

It is a medium-grained, white or yellowish-white rock with phenocrysts of quartz in a white felspathic mass with numerous limonitic pin points.

In section, there are numerous large columnar and irregularly outlined, slightly kaolinised platy phenocrysts of felspar and fewer rounded phenocrysts of quartz in a ground-mass made up of small laths and clouded plates of felspar with occasional small grains of quartz. In some cases the felspar phenocrysts are perforated by grains of quartz. The ground-mass is very fine-grained in some places, but with small patches of coarser felspar plates in others, and as these are usually fresh, they appear as if due to a re-crystallisation. Ferro-magnesians are almost wholly absent, being represented only by some few small yellowish to greenish chloritic scales and scaly aggregates.

The species of felspar present appears to be predominantly albite, and the rock is therefore a albite-quartz-porphyry.

It becomes evident then, that while one set—$\left[\frac{1}{102}\right]$ and $\left[\frac{1}{91}\right]$—are closely akin both in structure and in mineral composition, they are markedly different, especially in structure from the other—$\left[\frac{1}{877}\right]$. The latter is clearly an albite-quartz-porphyry, while the former have a structure intermediate between a granite-porphyry and a felspathic grit or arkose. In the absence, however, of means of comparing the felspars in the two sets, as well as of any opportunity of determining their field relations, owing to the limitations of the circumstances of their occurrence, an accurate statement of their genetic relationship is not possible, though, according to Mr. Clarke, from field evidence there is some reason to believe they are part of the same dyke mass.

(g.) *The Northern Outcrops.*

These are not associated with any mine workings and their connection, if any exists, with other porphyries in the area cannot be traced in the field. The outcrops are four in number:

(1.) Close to the Meekatharra to Peak Hill road, near the 68 M.P., occurs a white, fairly fine-grained, highly felspathic rock $\left[\frac{1}{113}\right]$, with a pale reddish tint on the weathered surfaces, and very small yellowish nests.

In section, the rock proves to be composed almost wholly of albite felspar, and is a white albite-porphyry or albitite. There are large rugged columnar and tabular phenocrysts of twinned albite in a fine-grained ground-mass of small plates and occasionally of short laths of the same mineral. In places in the slides, are pale, yellow-green, extremely fibrous chloritic aggregates and strings, and associated with them some opaque granules of doubtful

identity. Quartz appears to be entirely absent. An analysis of the rock in the Survey Laboratory gave these results:—

	I.	II.
SiO_2	68·85	68·7
Al_2O_3	17·95	19·5
Fe_2O_3	·79	..
MnO	*Nil*	..
MgO	·14	..
CaO	·19	..
Na_2O	10·40	11·8
K_2O	·02	..
TiO_2	·12	..
P_2O_5	Trace	..
H_2O	1·38	..
H_2O—	·09	..
FeS_2	·04	..
Total	99·97	100·0

I. $[\frac{1}{113}]$. Analyst, H. Bowley.
II. Analysis of pure albite: Dana, Text-book of Mineralogy (1900), p. 377.

The remarkable similarity of this analysis to that of pure albite is shown by Analysis II., cited for comparison.

(2.) In the vicinity of the previous outcrop, near the 68 M.P., occurs a rock which when weathered, is somewhat similar to $[\frac{1}{113}]$ but where fresh, is finer in grain and of a greenish-gray colour from the presence of numerous nests of greenish fibres. Typical specimens, *e.g.* [11202], consist in section of numerous phenocrysts of felspar in a holocrystalline ground-mass of small plates of felspar of varying size. The phenocrysts are slightly turbid but measurements indicate that the species is albite. No quartz phenocrysts were seen, nor, despite careful search, was any quartz distinguishable in the ground-mass. The crystals of the ground-mass vary much in size from small phenocrysts to minute grains. In the ground, are peculiar acicular, and curving or confused bundles of yellowish and greenish-yellow tint, and patches of thin needles and nests of the same mineral. These needles in places penetrate the phenocrysts. Owing to superposition of plates, and to low birefringence, they are indefinite in optical properties, but in the rock powder, they appear to be chloritic in character, possibly derived from a ferro-magnesian such as actinolite.

It is highly probable that both [11202] and $[\frac{1}{113}]$ though differing so far as the chloritic needles are concerned, are albite porphyries from the same rock mass, and represent dykes of the same age and origin.

(3) About 12 chains north-north-east of the 68 M.P. on the "Cut Track," occurs a dark-gray, mottled, flinty rock $[\frac{1}{103}]$, with numerous whitish phenocrysts of felspar and frequent small phenocrysts of quartz in a dark-gray flinty ground-mass. There are

numerous small phenocrysts of square, tabular, columnar and irregular forms of a highly turbid felspar, few square, triangular, and elongated phenocrysts of quartz and occasional flakes of greenish chlorite and rather rarely of greenish pleochroic hornblende, all in a microcrystalline platy ground-mass of felspar and quartz dotted thickly with minute grains of epidote and zoisite and scales of greenish chlorite. Grains of yellow or colourless epidote are often associated with the chlorite. The turbidity of the felspar is in part due to kaolin, in part to fine scales of mica, and in part to a development of granular epidote and zoisite.

This rock is a quartz-hornblende-porphyry or porphyrite. The species of felspar was undeterminable.

In this connection it is worthy of mention that about three miles north of Nannine, near the Racecourse, there occurs a rock $[\frac{1}{292}]$ very similar in external appearance to $[\frac{1}{103}]$ but darker in colour and with no quartz phenocrysts. In section also, the resemblance is close. There are in $[\frac{1}{292}]$ numerous partially kaolinised phenocrysts of felspar and rather frequent small ragged plates and prisms of greenish-yellow hornblende in a microcrystalline ground-mass of felspar plates dotted over with chlorite scales, epidote grains, and hornblende needles. The felspars, however, are frequently finely zoned, hornblende is more plentiful, the ground-mass is coarser and there are no quartz phenocrysts.

[11202] occurs rather close to this in the field, but the differences between them are so marked that on the evidence at present available they can scarcely be connected.

(4.) Finally, near the 57 M.P. on the "Cut Track" from Meekatharra to Peak Hill, there are outcrops of a rock which presents some unusual features. Specimens $[\frac{1}{112}]$ go to show that there are at least two varieties, well differentiated from one another.

(a.) A fine-grained, very dark, blackish-gray rock showing veinlets of clear quartz, occasional phenocrysts of felspar and quartz, and minute bundles or nests of black fibres. The latter are best seen on the weathered surfaces, where they appear as very fine needles or sheaves.

(b.) A variety exhibiting a passage from (a) into a rock of dark green colour, and apparently consisting of a ground-mass of quartz and felspar in which are innumerable radial and divergent groups of finely fibrous needles that cause the rock to resemble a minutely acicular amphibolite.

Microscopically, (a) consists of phenocrysts of both quartz and felspar in a fine-grained holocrystalline ground-mass of quartz and felspar plates. The phenocrysts of quartz are rounded with margins that have been more or less granulitised. There is a fine dust of undetermined nature all over the slide. Most noteworthy are long, thin groups of fine fibres, often curved, sheaf-like or diver-

gent, which from their blue-green colour and marked pleochroism at first sight appear to be tourmaline. Examination of the fibres, however, from crushed fragments of the rock, showed that they have the optical characters of amphibole, the bluish colour suggesting a species with combined soda. The needles penetrate both the quartz and felspar phenocrysts. In the ground-mass, several veinlets of quartz occur, and it is in these that much of the coloured mineral is found, the long axes of the needles being parallel to the vein.

In (b) there is a ground-mass consisting of small irregular plates as in (a), but without quartz, and containing large phenocrysts of felspar, but none of quartz. The remarkable feature of the slides, however, is that everywhere and in great amount are needles of varying thickness, separate and in divergent groups, of a greenish-yellow tint and with numerous pleochroic halos, probably round sphere granules. Nearly all the phenocrysts are penetrated by needles which are not, as in (a), bluish-green, but yellowish-green in colour. Moreover, they increase gradually in number to the exclusion of the felspathic mass, until the rock consists wholly of a plexus of needles of actinolitic hornblende and becomes an actinolitic amphibolite.

In the more felspathic portions of the rock mass are small greenish grains with marked absorption that closely resemble some varieties of tourmaline, but no tourmaline could be definitely identified.

Now, as both (a) and (b) have been collected as portions of the same rock mass, there are some points worthy of notice in regard to them. In the first place, where quartz is present, as in (a), and the porphyritic character is predominant, the amphibole is bluish in colour. As the amount of hornblende present increases the mineral loses its blue tone, and becomes yellowish-green; at the same time quartz seems to disappear, at any rate from among the phenocrysts. The porphyritic felspars, however, are still prominent. Finally, with further increase in the amount of actinolitic hornblende, and the disappearance of both the porphyritic felspars and the felspathic ground-mass, the rock becomes a fine-grained actinolitic amphibolite or hornblendite.

The origin of these peculiarities would seem to be that the specimens were taken from a junction between a quartz-porphyry (perhaps albitic) and an amphibolite or hornblendite. The variety (a) is certainly cracked, and exhibits uneven extinction, while the cracks in the ground-mass are filled with yellowish-green actinolite needles. The latter penetrate into the ground-mass but gradually disappear as their distance from the crack increases. It is, therefore, probable that there has been a partial assimilation of an amphibolite by an albite-quartz-porphyry.

Whether there is any genetic connection between $[\frac{1}{112}]$ and [11202] cannot be made out. Certainly quartz is absent from [11202], but as this constituent mineral is sometimes present and sometimes absent from different portions of the same dyke, *e.g.*, in the Paddy's Flat dyke, its presence or absence is scarcely a determining factor. A more important criterion is the character of the felspar in both, but this in the case of $[\frac{1}{112}]$ it has not yet been possible to establish.

(h) *The doubtful much weathered dykes.*

In several mines, viz., in the Hornsby, the Beverley, the Haveluck, Ralph's Patch, and the Jasper Star, white or yellow and red-stained kaolinic clays have been found, which are all that is left of the original rock at the depths to which mining in them has been carried on. While investigation of these clays with regard to their origin is always somewhat unsatisfactory, in these particular cases the common occurrence of intermixed quartz grains and the highly aluminous character of the clays are sufficient evidence to warrant the opinion that they represent former acid porphyry dykes, though of what variety they may be, there is no means of determining.

II.—Basic Igneous Rocks.

Included here are all those rocks to which, whether altered or not, a basic igneous origin is ascribed. According to their occurrence in the field, and, to some extent, so far as their structural characters are concerned, they are of either—

(A) Plutonic or Intrusive origin and not demonstrably volcanic; or

(B) Volcanic or eruptive origin.

(A) *Rocks of Plutonic or Intrusive origin.*

At the present juncture, for convenience in description and because it has been considered to be of more service to the mining community that the rocks should be described under names that, so far as possible, indicate their appearance in the field and enable them to be readily recognised, than that they should be referred to in strictly technical terms, these rocks have been arranged in the following two groups, depending on the degree and character of the alterations they have undergone:—

1. The comparatively fresh greenstones. In these the alterations have been due largely to thermo-dynamic action. The rocks, while differing considerably both in mode of occurrence and in appearance—some being almost black, others dark-green or gray-green, some occuring as intrusive dykes, others as small isolated peaks, or in masses of considerable size, some being massive and fine-grained,

other sheared and coarse-grained—all, nevertheless, agree in retaining definite and easily recognised traces of the original minerals and structure, and in exhibiting a very small development or complete absence of the alteration processes of carbonation, chloritisation and talcicisation.

2. Much altered, heavily carbonated, chloritised or talcicised rocks, in which traces of original structure and mineral composition are obscured and of which the origin and affinities are controversial.

1. *The comparatively fresh greenstones.*

The respective members of this group of which outcrops have been obtained in the field are as follows:—

(a) The fresh black dolerite, typically represented in the Ingliston Extended Mine;
(b) The norite of Barloweerie Peaks;
(c) The uralitised and zoisitised dolerites or gabbros, also called epidiorites;
(d) The epidotised quartz-dolerites;
(e) The actinolitic-zoisitic amphibolites of the Kyarra Mine;
(f) The fibrous-zoisitic amphibolites;
(g) The fine-grained dolerite of the Meekatharra Hills;
(h) The fine-grained zoisitic-amphibolites;
(i) The sheared amphibolites or hornblende schists, and foliated black ampibolites;
(j) Sheared amphibolites or epidiorites of Yaloginda;
(k) Kyarra schists;
(l) Serpentines.

(a) The Ingliston Extended Dolerite.

The distribution of this dyke is given in detail in the description of the Ingliston Extended Group in Chapter VI. (*q.v.*). The salient features, however, of its occurrence may be noted here. It is typically developed in the Ingliston Extended Mine, where it is found as an almost vertical dyke with a N.E. and S.W. strike in close contact with the black sheared rocks subsequently to be described under the title of "Black Schists." It is not, however, limited to this mine. Not only can it be traced on the same general course for nearly half a mile further north, but since it has been found possible by special treatment with balsam to obtain sections of various reddish clayey specimens in which undoubted relics of normal doleritic structure can be identified, it has been proved with a considerable degree of certainty to extend south of the Ingliston Extended. But instead of continuing on its normal course it turns sharply to the west, and cutting across the Paddy's Flat porphyry dyke, resumes its south-westerly course for about half a mile, though the indications of its presence are confined to

weathered specimens in some of the workings. A clear contact between the rock and any of the surrounding rocks has been discovered only in the Ingliston Extended Mine.

The dyke when fresh, *i.e.*, in the mine workings, is usually a rather fine-grained black rock. It varies, however, in texture, being in places coarse-grained, while at its contact with the "Black Schists," it is a dense-black, minutely grained porphyritic rock that must be regarded as a chilled margin. Above water-level, it is in places a reddish clay, in places a yellowish-green easily disintegrated rock which, on the dumps, exhibits spheroidal weathering.

A section of the fresh rock has already been described,* but additional sections show occasional rather large subhedral or rounded and irregularly platy crystals of greyish augite, and occasional columnar crystals of felspar in a finer-grained plexus of thin columns or laths of felspar with the interstices occupied by grains of the pyroxene and of black iron ore. The occurrence of the subhedral and platy crystals of augite and the larger columns of felspar give a suggestion of porphyritic structure to the rock. There are in places aggregates of small plates of augite, and in others, some aggregates of columns of felspar. The structure is distinctly ophitic. Quartz appears to be totally absent, and typically no trace of hornblende or mica could be found.

At the contact with the "Black Schists," the sections take on a tachylitic appearance, though no true tachylitic selvage has been found. They show a change from the ophitic structure of the mass to a structure in which thin columnar and lath-shaped phenocrysts of felspar and occasional phenocrysts of augite appear in a cryptocrystalline, glassy ground-mass densely charged with minute black granules, and with occasional microlites of felspar. Close to the contact these felspar phenocrysts lose their optical characters and become a minutely-grained mosaic, which, in polarised light, is in places scarcely distinguishable from the ground-mass, though in ordinary light, the laths and columns still stand out clearly in the ground. Moreover, the augite begins to lose its optical properties, and an aggregation of the black granules into irregular grains of appreciable size appears to take place.

Affinities of the Dolerite.

Dykes of very similar occurrence, appearance, structure, and composition have been noted previously from several localities. In the Bulletin dealing with the Sandstone area, a description is given of a fresh dolerite dyke which in places develops a tachylitic facies, though it exhibits no glassy selvage. In the Hidden Treasure Mine at Cue, a black fine-grained dolerite dyke is encountered in the

* Bull. G.S.W.A., No. 43.

granite. In the Crême d'Or Mine, at Cue, a dense-black porphyritic andesitic dolerite dyke also occurs, the andesitic character being undoubtedly the result of chilling of the margin of the rock. Again, in the Great Fingal Mine at Day Dawn, at the 1,300ft. level at the N.W. end of the ore-shoot, a dense-black dolerite dyke was seen by the writer, and at its contact with a quartz vein, a pronounced glassy selvage about a quarter of an inch in thickness has been developed. In none of these mines does the dolerite outcrop at the surface.

There can be no doubt that the dykes which occur at the Sandstone, Hidden Treasure, Crême d'Or, Great Fingall, and Ingliston Extended Mines are either portions of the same large and persistent dyke or are identical in age and origin. In the Sandstone Mines, there is indisputable evidence that the dolerite dyke crosses the quartz reefs. According to Mr. W. J. Turner, formerly manager of the Ingliston Extended Mine, there was an analogous occurrence in his mine, where during the course of mining operations a tongue of the dolerite was encountered crossing the lode.

(b) The Norite of Barloweerie Peaks.

At Barloweerie Peaks occurs a very fresh coarse-grained greyish-black rock with a vitreous and somewhat greasy lustre and with a prevailing reddish crust. In section, it proves to be a fresh hypersthene-gabbro. There are numerous short columnar and platy crystals of highly twinned basic labradorite forming here and there a coarse plexus, and in indistinct ophitic relation with them are crystals of pyroxene apparently of two species, diallage in rather ragged plates occasionally with schillerisation, and pale pinkish pleochroic hypersthene in large grains as well as plates, the latter sometimes with a fibrous greenish fringe of chloritic material irridescent in polarised light. The hypersthene also exhibits schillerisation as a peculiar minute striation resembling that in some lamellated felspar. The pyroxene forms that partially mould the felspars belong to the colourless species. No quartz was observed.

The rock resembles, both in the mass and in section, dykes occurring particularly abundantly at Norseman, and in isolated instances at Cue and elsewhere. In all cases, they have been regarded as probably the most recent of the basic igneous intrusions, though their chronological relation to the Ingliston Dolerite is uncertain.

(c.) *Uralitised and Zoisitised Diorites*—

(Epidiorites of some authors.)

Outcrops of these rocks have been found at various spots in the Meekatharra area. Perhaps the most typical development occurs near the Old Battery Group on the Garden Gully Road.

The rocks here are all of medium to rather fine grain, and vary from a light greyish-green rather fine-grained facies, such as **52d** [$\frac{1}{878}$], through a coarser grey-green to a medium-grained dark grey rock. In all cases, they consist of either light green or pale greyish uralitic hornblende prisms associated with pale yellowish-green or rather dark-grey saussuritised felspar.

In section, the specimens all consist of pale yellow-green almost colourless uralitic hornblende in ragged plates and prisms, all more or less intensely fibrous, particularly at the margins, associated with a varying amount of opaque grey granular zoisitised felspar. Some varieties, such as **52d** [$\frac{1}{878}$], consist almost entirely of the fibrous uralitic hornblende plates which, in places, have been mashed or broken down into aggregates of much smaller plates and, in others, into grey fibrous masses. In other varieties, a few cases of original colourless augite are observable. In others again, such as **53d** [$\frac{1}{879}$], there is a greater development of felspar in opaque grey granular aggregates, plates and columns, and a little interstitial quartz is present. Finally, in specimens like **54d** [$\frac{1}{879}$], there are large partially zoisitised platy and broad columnar crystals of basic labradorite. An approach to the ophitic structure of normal dolerites was observed in a few sections, particularly in **56d** [$\frac{1}{880}$], in which, also, are interstitial quartz and grey intensely fibrous and wavy colourless hornblende forms. In all varieties, orthopinacoidal twinning is common in the ferro-magnesian; ilmenite and leucoxene are rare, and quartz is but sparsely developed.

The original rock from which these have been derived appears to have varied from almost a pyroxenite (cf. **52d**) [$\frac{1}{878}$], through a coarse gabbro to a fine-grained gabbro or dolerite (cf. **56d**) [$\frac{1}{880}$]. Beyond the fact that serpentines occur associated with the rocks on their eastern and western flanks, nothing has been established in regard to their field relation.

Again, about 4½ miles west of the Old Battery Group, and about 4 or 5 miles south-west of the Kyarra Mine, are some hills from which two specimens have been obtained, one [$\frac{1}{303}$], a coarse-grained dark-green almost black rock with coarse greenish-black prisms of hornblende in a dark-grey saussuritic mass, and the other [$\frac{1}{304}$], a light grey-green rock with prisms of fibrous green hornblende in a preponderating white and greenish-white saussuritised felspathic mass.

In the former [$\frac{1}{303}$], there are large irregular platy crystals of pale-green nearly colourless uralitic hornblende, in more or less distinct ophitic relation with columnar crystals of kaolinised and zoisitised twinned felspar, and a little interstitial quartz. The felspar in the slides examined is in excess of the ferro-magnesian and the columns form areas of felspar plexus with small plates of quartz squeezed in between the forms. Original pyroxene cores are not visible but a kind of schiller appears in some of the uralitic plates. Rarely there occurs a ferro-magnesian plate which is

partly green, partly brown, a fact suggesting that portion of the hornblende may have been original. Ilmenite partially altered to leucoxene is not uncommon and is distinctly more prevalent than in the rocks from the Old Battery Group.

[$\frac{1}{304}$] is essentially similar to [$\frac{1}{303}$] in composition and structure except that in the former interstitial quartz is common, and a noteworthy feature of it is that, though separate, the plates in some areas all extinguish together, an indication of the simultaneous crystallisation of many of the interstitial quartz forms. Moreover, a decidedly ophitic structure has been retained.

Further, near the Jasper Star Workings there occurs a variety [$\frac{1}{290}$], which, in hand specimens, is almost identical with [$\frac{1}{304}$], the only difference being that hornblende and felspar are about equally developed. This rock, owing to its interesting characters, specially merits description. In section, the following minerals were determined :—

Uralitic hornblende, augite, felspar, quartz, epidote, zoisite, muscovite, chlorite.

There are long, sometimes thin columnar crystals of pale green, almost colourless fibrous uralitic hornblende, and large columnar and platy saussuritised felspar with subsidiary shapeless plates of quartz and, rarely, small areas of a micropegmatitic intergrowth of quartz and felspar. The uralitic columns are generally ragged at the ends and very frequently exhibit pronounced orthopinacoidal twinning. In places, they are quite curved. An especially noteworthy feature of the slides is the presence in considerable amount of original colourless augite. Cross-sections of this mineral occur quite frequently, and, generally, they also exhibit pronounced twinning. Moreover, it is not uncommon to find a core of unaltered augite in a plate of fibrous uralitic hornblende, and there are instances in which one-half of a twin has been altered to pale green uralite, while the other still retains the characters of augite. Further, in some of the hornblendic plates there are remains of a salite structure belonging to the original augite, a rim of fibrous uralite bounding an orthopinacoidal twin with the salite structure inside the rim. In some of the fibrous plates, there is a beautifully fibrous fringe, of which the fibres apparently penetrate into the felspar. Some long thin columns of colourless augite are also visible, as well as patches of pale green nearly colourless chlorite.

The felspar, in large plates and columns, is generally much altered, in part, to zoisite with a smaller amount of epidote, in part, to micaceous scales. In most cases it has the opaque grey granular appearance of saussurite with zoisite as the principal constituent. Ophitic structures, though noticeable in the partial moulding of the felspar columns by the ferro-magnesian, is not pronounced. Iron ores are conspicuously absent from the sections examined, but some small opaque forms may be leucoxene.

This rock is a fine specimen of a coarse-grained partially uralitised and saussuritised micropegmatitic quartz-dolerite or gabbro, in which undoubted original augite occurs in process of alteration to fibrous uralitic hornblende.

Yet again, at Mount Obal (**K6**) two varieties have been found outcropping, a grey-green rock, represented by [$\frac{1}{309}$] and [**11317**], that is undoubtedly similar to [$\frac{1}{290}$] except for the absence of original augite, and a very fine-grained dark grey-green facies represented by [**11318**].

The specimens of the former rock calls for no individual description. They are both uralitised and saussuritised quartz dolerites.

[**11318**], however, is an important facies, but, since its characters agree rather with those of zoisite amphibolites than with the uralitised dolerites, it will be considered in the latter group.

Finally, another outcrop, the most northerly from which specimens have been obtained in the District, occurs just south of the Belele Station. This is again, **446c** [$\frac{1}{881}$], a grey-green rock composed almost wholly of greenish hornblende prisms separated by pale greenish-white saussuritised felspar in small amount. The mass shows some slight differentiation into portions of highly felspathic character and portions composed mostly of hornblende. In the latter there is noticeable a suggestion of schistosity. Beyond the fact that the rock is found in close association with a brownish-black serpentine nothing is known of its field relations. It is essentially the same as [$\frac{1}{309}$] both in composition and structure.

(*d.*) *The Epidotised Quartz-Dolerites*—

Somewhat similar to the members of the previous group, but epidotised instead of saussuritised, chloritised rather than uralitised, and with yellow epidote easily visible in the hand specimens, are an outcrop represented by [$\frac{1}{293}$] and [**11206**] from about three-quarter mile east of the Globe, and an outcrop represented by **17d** [$\frac{1}{882}$], which occurs associated with the crystal tuff about $1\frac{1}{4}$ miles South-East of the S.E. corner of Gwalia Extended (G.M.L 872N). The rocks are all dark green medium-grained, considerably epidotised quartz-dolerites.

[$\frac{1}{293}$] in section shows the following minerals:—Augite, chlorite, epidote, felspar, quartz, apatite, leucoxene, muscovite, zoisite, and calcite.

These are large, very irregular plates of a greyish violet augite, frequently wholly or partially decomposed to green chlorite and epidote, in ophitic relation with numerous columnar crystals of felspar that are in places micacised, in places altered to an opaque grey granular aggregate of epidote grains.

The augite frequently exhibits fine striation, a development of chlorite along the margins and along cleavage cracks, and invariably has a dusty appearance. The felspar has the lamellation as a rule obscured by alteration in part to mica scales, in part to

yellowish epidote, in part to greenish chlorite. The columnar euhedral crystals are frequently completely moulded by the pyroxene, or form a plexus of which the interspaces are occupied by shapeless plates of quartz or epidote. Yellowish-green epidote is particularly abundant, and is the product of the alteration at times of felspar, at times of the pyroxene. Apatite needles are not rare. Leucoxene is present in large irregular masses which sometimes completely enclose columnar felspars.

[**11206**] is essentially identical with $[\frac{1}{293}]$, though more strongly epidotised and with a smaller development of augite.

$[\frac{1}{882}]$, though from a different outcrop differs only in being still more strongly epidotised and chloritised than the other members of the group, and in the presence in the rock mass of finely foliated yellowish bands that are composed of folia of granular epidote alternating with bands of quartz. It is noteworthy, also, that the epidotic folia consists in places of fine micropegmatite in which columnar epidotised felspars appear, and some areas of leucoxene. These bands have the appearance in section of a highly epidotised felspar-quartz micropegmatitic facies of a quartz dolerite.

Owing to the smallness of the outcrop $[\frac{1}{882}]$ is not distinguished on the map from the volcanic rocks.

(*e.*) *The Actinolitic-Zoisitic Rocks*—

The rocks here included have been found in two localities, viz., in the Kyarra Mine, and flanking the uralitised dolerites near the Old Battery group close to Garden Gully. Specimens have been obtained, for example, 30 chains south of the main shaft, Kyarra Mine, at the 100ft. level, north crosscut $[\frac{1}{295}]$, about $11\frac{1}{2}$ chains west-south-west of the main shaft, Old Battery Group $[\frac{1}{297}]$; about three chains west-south-west $[\frac{1}{300}]$ and about 10 chains west of the same main shaft $[\frac{1}{301}]$.

Owing to the obscurity of the outcrops both on the surface and in the mines, their field relations are indefinite.

In hand specimens, the rocks are fine-grained, dark-greyish-green in colour, with a fairly distinct felted appearance on the fresh fracture, due to interlacing of numerous small needles of greenish hornblende. The needles vary in size from $\frac{1}{8}$in. to $\frac{3}{8}$in. in length.

In section, the specimens consist generally of minutely and intensely feathery fibrous areas of hornblende needles in wavy, curved aggregates, with here and there long thin columnar fibrous crystals crossing the orientation of the fibrous aggregates at fairly steep angles. Rarely, remains of felspar plates and small columns appear, and there is little doubt that plates of felspar are obscured, owing to being shot through with hornblendic needles. In the aggregates of the latter are numerous small opaque grey granular aggregates mostly of zoisitic material, an alteration product of pre-existing felspar. In the aggregates, also, are rare

kernels of colourless hornblende that are not fibrous. Occasional ortho-pinacoidal twinning is noticeable in the hornblende prisms. Numerous minute zoisite grains are scattered through the fibrous aggregate (Fig. 77).

Fig. 77.

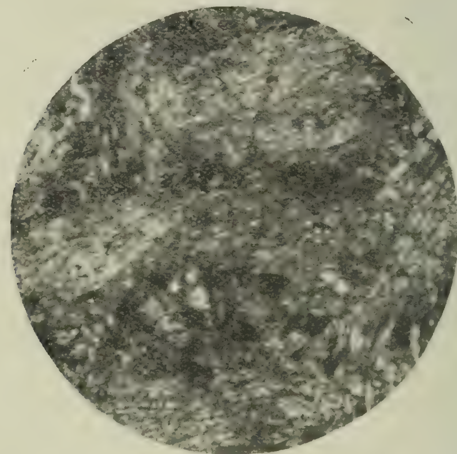


Photo: R. A. F. Neg. 1236.

Microphotograph [$\frac{1}{208}$].—Showing individual fibrous prismatic forms of actinolitic hornblende. The interspaces are occupied by needles of hornblende and zoisite grains.

Some specimens consist of patches of peculiar opaque greyish granular and rod-like forms resembling long thin opaque needles, and frequently divergent, and some areas are composed wholly of different groups of these rods forming a felt or plexus. They prove to consist largely of needles and fibres of colourless hornblende separated by strings of zoisitic material. Confused feathery minutely fibrous areas are also frequently visible.

Again there are varieties in which the actinolitic prisms have a green colour, are very numerous, and form a kind of loose plexus in the finely fibrous zoisitic mass, and in these varieties there are undoubted remains of thin columnar or lath-shaped felspar and some doubtful interstitial quartz.

An extremely schistose or sheared variety with marked parallel orientation of the prisms, rods and fibres, and with rare, doubtful cores of augite occurs about three chains west of the Main Shaft in the Old Battery Group.

(*f*.) *The Fibrous Zoisitic Amphibolites*.—

These rocks, though differing microscopically to some extent from both the uralitised and the actinolitic-zoisitic rocks, never-

theless closely resemble them in external appearance. Typical representatives are [$\frac{1}{337}$], [$\frac{1}{336}$] and [$\frac{1}{346}$].

[$\frac{1}{337}$] from a hillock 30 chains south of the New Chum Group, is in hand specimens a fine-grained massive grey-green rock with reddish crust. In section, in ordinary light, it consists of opaque, grey, fibrous, more or less platy forms amongst which are numerous clear areas of various quadrangular shapes with one or more clear-cut boundaries.

With polarised light, sections show a confused fibrous mass of large and small curved, contorted and wavy plates of colourless hornblende, amongst which are numerous small gray granular aggregates of epidote and zoisite. The clear areas prove to be in part a fine-grained mosaic, in part irregular, partially granulitised plates of felspar. It is probable that the mosaic forms consist of granular albite representing original felspar much obscured by needles of the fibrous hornblende. The original structure is very obscure, but in ordinary light there is a suggestion of ophitic relation between the mosaic forms and the grey fibrous forms. This rock resembles a saussuritised uralitised, intensely fibrous form of the altered dolerite $\frac{1}{304}$.

[$\frac{1}{336}$] from about 60 chains south of the New Chum Group, is a medium-grained grey-green sheared fibrous rock composed of indistinct reticulated and radiated groups of hornblende prisms in a pale-greenish saussuritic mass. In section, the rock consists of a coarse-grained, very fibrous, contorted and confused mass of ragged plates of colourless hornblende, and occasional rounded more or less unsheared plates of the same mineral, with the interstices occupied by very indistinct microcrystalline mosaic in which small felspar columns occur, but which is much obscured by the hornblendic fibres. Numerous opaque gray granular zoisitic and perhaps epidotic grains are scattered over the slides. Definite traces of original structure have been obliterated, but the fibrous plates, owing to the shearing, are arranged in imperfect bands with the obscure mosaic between them.

This rock is a sheared almost schistose finely fibrous platy amphibolite or epidiorite, with resemblance both to [$\frac{1}{301}$] and [$\frac{1}{346}$] described later.

[$\frac{1}{346}$], from just west of [$\frac{1}{337}$] is a sheared dull, grey-green rock, resembling in the appearance of the cross-fracture, the actinolitic-zoisitic rocks but without the distinct needles. In section, it consists of numerous large indistinctly platy and columnar, colourless and intensely fibrous forms of hornblende arranged, in general, in similar alignment, and separated by opaque gray areas of fine granular zoisite. No felspar is discernible, unless some microcrystalline mosaic represents it. The gray granular areas are exactly the same as those seen in the spheroidal fine-grained amphibolites in the North End of Kalgoorlie, which are described in the Bulletin on the North End, Part III. These specimens

are all confused, finely-fibrous platy amphibolites or epidiorites. The resemblance in particular between [$\frac{1}{326}$] and [$\frac{1}{346}$] on the one hand, and the grey-green uralitised and zoisitised dolerites or epidiorites on the other, is striking, and in [$\frac{1}{336}$] the radial or felted character of the surface is not markedly different from the structure in the actinolitic-zoisitic rocks.

(*g.*) *The green, fine grained Basaltic Dolerite of the Meeka Hills* ;—

This rock forms the Meeka Hills, about seven miles south of Paddy's Flat.

In hand specimens, it is a minutely-grained, almost flinty, dark grey-green rock with prevailing reddish crust.

In section, it consists of a very fine-grained mass of very small columns or laths of felspar, frequently indistinct from alteration, disposed in a loose plexus, and numerous small, faintly pink and grayish plates and grains of augite occupying the spaces between the felspars. The augite is in part altered to a green chlorite with the production of some granular calcite, small grains of which are scattered sporadically through the slide. Rarely there are large patches of calcite associated with chlorite—the latter penetrated by felspar laths—which doubtless represent a former large augite crystal, and occasionally a larger columnar crystal now composed of chlorite, scales of mica, and some granular epidote represents a phenocryst probably of felspar. Most of the felspar laths are partially micacised, others are altered to a grey, granular, opaque mass of epidote and zoisite. A little granular quartz was observed, and epidote grains are common throughout the slides.

(*h.*) *The fine-grained Zoisitic-Amphibolites* :—

About 10 chains north of the Main Shaft, Old Battery Group, there outcrops a very fine-grained dark gray-green rock with a slight tendency to shear structure [$\frac{1}{302}$]. In section, this consists of numerous small stumpy, ragged fibrous prisms, rods and needles of colourless hornblende separated by much minutely granular zoisite. A little quartz occurs interstitially. The hornblendic fibres, however, have in general a tendency to parallel orientation, so that, when weathered, the rock has a somewhat schistose structure. The large hornblende forms are sheafy and fibrous. Felspars, though probably present as thin laths, are quite obscure and unidentifiable. This fine-grained zoisitic amphibolite is essentially similar to that from the Cue Trig.

Again, in the Bottom Level of Shaft 5 of the Sirdar Group, occurs a weathered, yellowish-green, very fine-grained slightly sheared rock, with a tendency to schistosity. This is almost exactly similar to [$\frac{1}{302}$] above, but finer in grain and with a smaller development of zoisite. In section, it consists of a felted mass of minute needles of colourless hornblende arranged in countless small, more or less parallel, slightly undulating strings, but with many needles

at all angles to the direction of the shearing. Grains of epidote and zoisite are scattered through the felt, and there are some minute clear grains of albite and possibly of quartz. The structure is distinctly minutely schistose.

Further, at Mount Obal, K6, about half a mile north of the Trig, there outcrops a fine-grained dark gray-green rock with a suggestion of jointing, and similar in appearance to [$\frac{1}{302}$]. It consists, in section, of a felted mass of almost colourless needles of hornblende, aggregated into fine tufts, radiated, sheafy, and divergent groups and strings, while between the fibres are minute grains of zoisite and, occasionally, traces of small rods or laths of altered (kaolinised) felspar. A very little interstitial quartz, a little granular calcite, and small grains of iron ore are also present. In ordinary light, the slides appear opaque from the presence of very small gray granular aggregates of zoisite grains, derived probably from pre-existing lime-soda felspar. The structure of the rock is confused, not distinctly igneous, and the rock must be regarded as a fine-grained zoisite-epidiorite. There is a striking similarity between it and such fine-grained zoisite-amphibolites from Kalgoorlie as [**2950**]. The significance of the rock will be discussed in the following section.

The Origin and Relationship of Groups (c.), (d.), (e.), (f.), (g.), (h.) :—

These groups comprise : the uralitised dolerites, the epidotised dolerites, the actinolitic-zoisitic amphibolites, the fibrous zoisitic amphibolites, the fine-grained green dolerite of the Meeka Hills, and the fine-grained zoisitic amphibolites.

The outcrops of the rock are generally separated by considerable intervals, and as, in many cases, the intervening rocks do not outcrop but are covered by a thick overburden, and since, even in those cases where they do outcrop, no junctions can be seen, it is not practicable to obtain much information as to the field relations of the rocks, though some ascertained facts are of importance. Nevertheless, particularly in the groups considered, there are microscopic resemblances between members of the various groups, and occurrences of intermediate varieties, which afford reasonable ground for the assertion of genetic connection between the groups.

The similarities in some cases are very strong. The uralitised dolerites from near the Old Battery Group, and the rocks both from the Jasper Star workings and from Mt. Obal, are so closely akin both in the mass and under the microscope, that they must be regarded as contemporaneous intrusions of similar character from the same magma ; and this statement is true of all the uralitised dolerites. In the case of the other groups, however, the similarities are less striking, but still sufficiently strong in the absence of other criteria to serve as indications of genetic connections.

Mention has already been made of the intensely fibrous zoisitic patches in such rocks as 52d [$\frac{1}{878}$], obviously derived from uralitic hornblende which occurs in the rocks. These patches are almost identical with sections both of some of the actinolitic zoisitic rocks and of fine-grained zoisitic amphibolites such as [**11318**]. Moreover, [**11318**] is in section closely allied both to varieties of the actinolitic-zoisitic rock, *e.g.*, [$\frac{1}{297}$], and to [$\frac{1}{302}$], the fine-grained fibrous amphibolite, and as [**11318**], when traced along its strike, passes into a uralitised and zoisitised dolerite [$\frac{1}{309}$], the connection between these actinolitic rocks and the uralitic quartz dolerites becomes fairly strong. This connection is further strengthened by the fact that the actinolitic rocks have been observed on the flanks of the uralitised types near the Old Battery and—to cite an example from another field—they have been found to pass into a gray-green uralitised and zoisitised dolerite identical with [$\frac{1}{290}$] or [$\frac{1}{309}$] at the corner of Hinemoa and Bulwer Streets, in Kalgoorlie. Further, [$\frac{1}{336}$], in which the radial prismatic or actinolitic structure of [$\frac{1}{297}$], and the appearance in hand specimens of the uralitised group are easily recognised, shows marked resemblance both in appearance and structure to the actinolitic-zoisitic rocks and to the uralitised dolerites. There is, also, a close similarity between [**11318**] and [$\frac{1}{346}$] in structure, and between [$\frac{1}{346}$] and [$\frac{1}{336}$] in both external appearance and microscopic structure. Again, between [$\frac{1}{302}$]—the fine-grained zoisitic amphibolite—and [**11318**] there is a very considerable degree of resemblance both in appearance and structure, while an equally close similarity in structure though more remote in external characters obtains between [$\frac{1}{337}$] on the one hand and [$\frac{1}{297}$] and [**11318**] on the other.

There can be little doubt, therefore, that the actinolitic-zoisitic and the uralitised and zoisitised groups are either separate intrusives from the same rock mass and probably contemporaneous—which their occurrence in the Kyarra Mine, unconnected, so far as can be seen, with any uralitised dolerite, would tend to show—or the former are chilled margins to the intrusions of the uralitised rocks—which their occurrence on the flanks of the latter at the Old Battery Group strongly suggests.

The connection between these rocks, however, and the fine-grained amphibolites such as [$\frac{1}{302}$] is less clearly determinable. The occurrence of the fine-grained green dolerite [$\frac{1}{334}$] has already been noted. Both [$\frac{1}{302}$] and [$\frac{1}{341}$] show a marked resemblance to [$\frac{1}{334}$] in the characters of the hand specimen, while, in section, if allowance is made for the alteration of augite to fibrous hornblende—an alteration quite feasible as the result of shearing, of which both $\frac{1}{302}$ and $\frac{1}{341}$ bear evidence they are also remarkably similar. There is little doubt that both these rocks have, in fact, been derived by dynamic and chemical action from a fine-grained dolerite such as [$\frac{1}{334}$]. Now, the genetic connection depends on the relation

between $[\frac{1}{302}]$ and **[11318]**, and both in the mass and in section these are closely similar. **[11318]** occurs near Mt. Obal (K6), while $[\frac{1}{334}]$ forms the Meeka Hills, so that, so far as is known, there is nothing in the field relations of the two rocks to militate against a connection between them. But whether $[\frac{1}{334}]$ occurs as a dyke or as a volcanic plug cannot be established. Assuming the validity of the connection between the two rocks, it is obvious that for some reason $[\frac{1}{334}]$ has escaped the metamorphic action that has altered **[11318]**, $[\frac{1}{302}]$, and $[\frac{1}{341}]$ into fine fibrous amphibolites. The essential identity of $[\frac{1}{302}]$, in particular, to the zoisite-amphibolite of the Cue Trig has already been noted.

An attempt has been made in Fig. 25, to show in graphic form the inter-relationships and positions of the members of the groups. In the figure, the clearly established connections are shown in continuous lines, the less distinct, or doubtful connections in interrupted lines. Heavy lines lead from those least altered from the original to their derivatives. Thin lines connect rocks almost equally metamorphosed.

The chloritised and epidotised quartz-dolerites—Group (*d*)—are of uncertain affinities. As has been noted already, they outcrop two localities, one about 10 chains east of Water Reserve 12245, and the other, north of this, a little over a mile south-east of the S.E. corner of the Gwalia Extended. While, in the former, their relations with the surrounding rocks are observed, in the latter outcrop, they occur associated with rocks which have an undoubted volcanic character. Since even in this case, however, according to Mr. Clarke, their field relations cannot be ascertained owing to the comparatively flat surface and more or less weathered state of the outcrop, it is impossible to state whether they belong to the volcanic series of flows or sills, or are—as would appear more probable from their microscopic characters—intrusive dykes. Though differing from the uralitised dolerites principally in the character of the alteration only, no connection between the two groups can be traced. A somewhat analogous case occurs in Kalgoorlie, where besides the uralitised dolerites, there are large masses of a chloritised, in places epidotised and carbonated quartz dolerite.

(*i.*) *The sheared amphibolites or Hornblende Schists and the foliated dense-black Amphibolites.*

THE SHEARED AMPHIBOLITES OR HORNBLENDE SCHISTS.

The best development of these rocks in the Area occurs at the Batavia workings, though a belt of them extends from the southern limit of the Area to a little north of these workings.

The rocks vary from fine to coarse grain, are fresh and dark-green in colour, are generally sheared into an imperfect schistosity, and in some cases are penetrated by lenticular veins of quartz,

which run parallel to the schistosity. A considerable amount of iron pyrites is frequently noticeable in them.

In section, the rocks consist of imperfect thin bands of small fibrous ragged prisms and needles of green pleochroic hornblende separated rather indefinitely by small rounded lenticular or linear areas of clear felspar-quartz mosaic which has been produced by granulitisation of pre-existing felspar and probably quartz. Fine needles of hornblende occur, also, distributed through the mosaic, and there are aggregates and small grains of magnetite. Most of the fibrous prisms and needles have a more or less parallel orientation, produced by dynamic strain. All trace of former typical igneous structure has been obliterated. In some sections, the parallel alignment of the hornblende plates is more distinct and the plates are perforated, and frequently a wavy structure has been induced in them. In all cases, the species of felspar cannot be made out, but occasionally the plates are untwinned. The absence of definite igneous structure and the composition ally these rocks more with the schistose or sheared epidiorites than with hornblende schists.

In connection with this group mention must be made of a rock [$\frac{1}{306}$] which occurs about four miles south-east of the Kyarra Mine, and about $1\frac{3}{4}$ miles east of the 30-Mile Post, Garden Gully Road. This is a dark-green coarse-grained, highly sheared amphibolitic rock, with occasional white patches of felspathic material. In section the rock consists mostly of large, irregular, platy and fewer prismatic crystals of hornblende, pleochroic in green to yellowish tones. The interstices between the plates are occupied by a mixture of comparatively small irregular plates of a kaolinised untwinned felspar and plates of highly kaolinised finely lamellated plagioclase with plates of clear quartz at times forming a mosaic. In places, the felspar outlines are idiomorphic to the hornblende on the edges of the quartz-felspar areas. The species of felspar present are again difficult to determine, but the plagioclase appears to have a small extinction angle on symmetrical lamellæ, and the untwinned plates appear to be orthoclase. Some of the crystals show a suggestion of the cross-hatching of microcline, but this is to be regarded rather as the result of dynamic strain than as a primary character. Some slight degree of granulation of the quartz and felspar, frequent bending and pinching of the hornblende plates, and a production of a fibrous structure in the hornblende are attributable to the same influence.

The affinities of this rock are with quartz-diorites, but on account of similarities to the Batavia schists, and the absence of evidence to the contrary, it has been mapped as of the same series as these rocks. Associated with it in the field are finely foliated, yellowish, fine-grained bands of epidote, zoisite and quartz.

The fine-grained Foliated and dense-black Amphibolites.

Isolated outcrops of a dense black, hard, fine-grained, foliated or sheared amphibolite occur at several spots. They are represented by :—

[**11314**] from the western margin of the granite about $1\frac{3}{4}$ miles east of the 30-Mile Post on the Nannine-Abbott's Road.

[$\frac{1}{333}$] also from the western margin, on the track to the Sabbath Mine from Garden Gully Road, about $1\frac{1}{2}$ miles north-west of the 27-Mile Post on the Garden Gully Road.

[$\frac{1}{354}$] from Annean Hill (K_2).

These rocks all agree in being very dense, black, and very hard, and more or less finely foliated. In some sections, as in those of [**11314**], they consist of a minutely grained mass of small ragged plates of partially chloritised hornblende aligned in sensibly parallel thin bands separated by minute mosaic. In others as in the case of [$\frac{1}{333}$], the hornblende is in thin elongated scales arranged in folia with their long axes parallel to the foliation, separated by minute granular mosaic apparently of felspar, with granules of zoisite and some quartz. The yellowish patches visible in the rock mass consist of epidote and zoisite grains and chlorite scales. Finally, in [$\frac{1}{354}$] there is a very dense finely-fibrous mass of hornblendic needles in patches, in imperfect bands, and with some needles of actinolitic greenish hornblende of appreciable size. The minute needles, in many cases, are seen to be enclosed in indistinct felspar plates, which have sometimes been altered to a fine-granular material, probably a mixture of epidote and zoisite. In some parts of the slides the appearance suggests felspar plates full of minute hornblende needles.

In addition to these outcrops there are others of less dense but finely-foliated hornblende rocks, such as occur where the Telegraph Line crosses the eastern margin of the granite ; and again east of the Chunder Loo Mine.

The former are represented by *45d* [$\frac{1}{883}$]. This is a very minutely foliated wavy, dark grayish-green, dense rock with marked crinkling on the plane surfaces at right angles to the foliation. In places, small knots of whitish felspathic material are visible on the foliation surfaces. In section, some slides are finely foliated with folia or strings of scaly hornblende or chlorite separated by folia of kaolinised and micacised felspar, quartz grains, and occasional strings of quartz mosaic. Calcite grains, epidote and zoisite grains are associated with the quartz-felspar folia. In other slides, large epidotised and zoisitised felspars occur, which form the knots visible in the mass. In these slides there are imperfect strings of perforated prisms of green hornblende, and associated with them are nearly colourless or pale-green pla which, from their large angle of extinction, are referred to almost colourless monoclinic pyroxene. In part these plates are altered to green actinolitic hornblende.

There are varieties represented by a specimen collected by Mr. A. Gibb-Maitland [**11212**] from about the same locality, which are grayish-green in colour and extremely finely foliated. On the foliation surfaces, the specimen [**11212**] rather resembles a fine-grained variety of [$\frac{1}{290}$]. In section, the rock is an extremely pyroxenic facies of 45*d* [$\frac{1}{883}$], consisting of numerous very irregular plates of the pale-green mineral in a highly kaolinised felspathic mass. The green plates, however, frequently not only mould felspar crystals but completely enclose them. There are numerous grains of sphene, and in places, a change from the pale green mineral to a deep green pleochroic hornblende. In some portions of the slides, indeed, hornblende is the only ferro-magnesian visible. Zoisite and epidote grains are common, and an incipient foliation is noticeable.

It is evident, therefore, that the different specimens of 45*d* [$\frac{1}{883}$] are but variations of a finely-foliated type such as [**11212**].

The outcrops east of the Chunder Loo are represented by 41*d* [$\frac{1}{884}$], and 43*d* [$\frac{1}{885}$]. The former is a rather coarse-grained schistose rock in which the hornblende is in long thin ragged columns or prisms arranged in more or less parallel imperfect bands. The mineral is sometimes in tufts of fibres, sometimes in fibrous prisms, and sometimes—especially in the areas of fine felspathic mosaic that separate the hornblende bands—in small, almost colourless tufts, nests and fibrous sheaves.

[$\frac{1}{885}$] 43*d* is much finer in grain, a finely-foliated hornblende schist with occasional well-defined aplite and pegmatite veinlets.

The Relationship of the Rocks.

The establishment of the relationships of the members of this Group, scattered as the outcrops are in distribution, with distinct differences both in composition and structure, and, with no connecting links in the field, is a matter of considerable difficulty. The dense-black amphibolites or epidiorites are, with little doubt, varieties of the same rock, but the finely foliated specimens such as [$\frac{1}{883}$], [$\frac{1}{885}$] and [$\frac{1}{884}$], are by no means obviously connected with them. The resemblance, however, between [$\frac{1}{883}$] and [**11314**], both so far as their general characters in the mass are concerned, such as colour, foliated structure, mineral composition, and the persistence of the peculiar crinkling on the foliation planes ; the similarity between the dense-black amphibolites and [$\frac{1}{884}$], and the close correspondence between [$\frac{1}{884}$] and [$\frac{1}{207}$] from Batavia, both in hand specimens and in microscopic characters ; these all render it highly probable that the various members are only different manifestations of the one rock mass. Of what nature this mass originally was, there is no evidence, though the characters of the dense-black amphibolites are not unlike those of fine-grained amphibolites to which an origin for ancient lavas has been ascribed.

(j.) The Sheared Amphibolites and Epidiorites of Yaloginda.

Nearly all the rocks in the neighbourhood of Yaloginda have been reduced by alteration to clays, so that any differences in origin, mineral composition and structure, have been largely obliterated. In general, however, they show sufficient similarity in colour, in fineness of grain, in structure, in mineral composition when fresh, and in decomposition products, to warrant their being placed all in the same group ; and, though it will be seen from the descriptions which follow that they are similar in character to the fine-grained amphibolites already considered, nevertheless, the definiteness of the locality of their occurrence, the definite presence of shearing and the general uniformity in their characters entitle them to separate consideration.

In the field, the fresher specimens are yellowish-green, or rather pale-green, fine-grained rocks with a more or less distinct schistosity or sheared structure. The clayey rocks are greenish, yellowish-green, yellow or gray, are frequently sheared and are all fine-grained. The freshest specimens obtained are represented by [$\frac{1}{341}$] from the Sirdar Group, bottom level of Shaft 5 ; and [$\frac{1}{347}$] from the dump of Shaft 21 in the Kelpy Group.

The former, [$\frac{1}{341}$], is a weathered, yellowish-green, very fine-grained, slightly sheared rock. In section it consists of a felted mass of minute needles of colourless hornblende arranged in innumerable small, more or less parallel and undulating strings, but with numerous needles at all angles to the general alignment. Scattered all through the felt are numerous small grains of zoisite and, probably, of epidote. There are also occasional minute clear grains of albite. The structure is distinctly minutely schistose.

From these characters, the rock is a fine-grained sheared or schistose zoisite-amphibolite or epidiorite.

[$\frac{1}{347}$] is a highly sheared or schistose grayish-green flaky rock distinctly fibrous in cross section. Microscopically, it is a highly sheared intensely fibrous hornblendite or epidiorite consisting of numerous fibrous plates or aggregates of fibres curved and undulating, but mostly arranged in parallel alignment, with occasional "augen" of fairly clear felspar, or with strings of felspar mosaic As many of the "augen" are granulated at the corners, the mosaic is doubtless due to the breaking down of the original felspar plates. In the fibrous mass, there are here and there pale-greenish plates of non-fibrous actinolitic hornblende. The appearance of the slides suggests an origin from a pyroxenite or gabbro similar to $\frac{1}{878}$. and there is also in the fibrous structure with the pale-green non-fibrous prisms, a close resemblance to some of the actinolitic-zoisitic rocks. Zoisite, however, if present, is in very small amount. There are grains perhaps referable to leucoxene.

From these two specimens, therefore, which may be taken as typical of the Yaloginda greenstones, there is evident, in [$\frac{1}{341}$],

a marked resemblance to [$\frac{1}{302}$] one of the fine-grained fibrous zoisitic-amphibolites, a resemblance almost amounting to an identity. Moreover, in [$\frac{1}{347}$], there is also a marked similarity to both the actinolitic-zoisitic rocks and to the pyroxenic varieties of the uralitic dolerites. Consequently, though it is impossible to map, in detail, the Yaloginda rocks, there is little doubt that they consist of largely, if not wholly, of sheared fine-grained zoisitic and intensely fibrous epidiorites, in all respects except the shearing comparable to those already described.

Of the weathered specimens, little can be stated, though many slides have been examined. Some specimens are dark green foliated chloritic and talcose rocks, while others are greenish clays composed of fibrous green chloritic material. [$\frac{1}{345}$] from Shaft 13ft. V.D., south of the S.W. Peg. of the Kelpy South G.M.L., which is a pale grayish-green talcose rock of fine-grain, differs slightly from the normal specimens in consisting apparently of a mass of pale-green chloritic and talc scales and patches with numerous colourless tremolitic needles. [$\frac{1}{344}$] again, from Shaft 11, on the Black Jack Group, indicates, in the presence of leucoxene patches and fibrous hornblendic forms, an affinity with some coarse dolerites. The slides of the weathered specimens, however, have not been found to show characters of any real petrological importance.

According to Mr. Clarke, these schists or sheared rocks of Yaloginda are important, as they form the country both of the small, sometimes rich veins of the vicinity, and of the "lode formations" in the Karangahaki Belt.

(*k.*) *The Kyarra Schists*:—

In the Kyarra Mine, in the Main Shaft, at a vertical depth of about 280ft., specimens of a rock of somewhat peculiar character were obtained. These are all extremely weathered and brittle, and, consequently, very difficult to section. In external appearance, they are dull grayish-green, soft and friable, extremely schistose, with thin streaks of greenish chlorite on the surface of schistosity, and with indistinct small white felspars on the cross fracture.

In some sections, there are apparent phenocrysts of felspar very turbid from kaolinisation, rather ragged in outline and frequently chloritised, in a ground-mass of fine mosaic very unevenly distributed. In addition to the felspar, are small plates of quartz. Scaly strings of pale yellow-green chlorite occur sporadically, and there are numerous small ragged patches of opaque, gray, granular material, white by incident light, of uncertain identity. In other sections, there are pronounced shearing or dynamic effects. The yellow-green chloritic strings are frequent, wavy and undulating, and curving round the felspar forms, causing the latter to appear as "augen." Associated with them are colourless highly birefringent scaly aggregates and strings of a talcose or sericitic character, probably the latter. The felspathic crystals are rather

frequent, and at first sight the rock has the appearance of a coarse gabbro or dolerite in which the felspars are very kaolinised and the ferro-magnesians altered to yellow-green chlorite. The origin of the mosaic is uncertain, whether a matrix, a ground-mass enclosing the felspars as phenocrysts, or produced by the disintegration of larger felspar plates. There is no doubt that some disintegration has occurred, the margins of most of the felspars being considerably granulated ; and this fact in conjunction with the uneven distribution of the mosaic suggests that the last-mentioned origin is the most probable. Frequent small, nearly black opaque grains, white by incident light, resemble leucoxene but are not certainly this mineral.

The origin of the rock is doubtful, but its microscopic appearance, though indistinctly porphyritic, seems to point to the rock being an intensely sheared, schistose and considerably granulated chloritised dolerite. This view is, to some extent, supported by the occurrence, already noted, of actinolitic-zoisitic rocks in the Kyarra, that are in all probability derived from gabbros or dolerites. The field relation, however, of the two types are nowhere to be made out.

(*l.*) *The Serpentines* :—

Outcrops of these rocks have been found on hills about two miles south of Belele Homestead, which is about 17 miles to the west of Meekatharra ; on the eastern margin of the uralitised dolerites near the Old Battery ; and at the north end of the Karangahaki Group.

As these rocks exhibit characters which are not all alike, and of which some will be of importance when the black Schists and the talc-chlorite-carbonate rocks come to be considered, it is advisable to describe them in some detail.

The most northerly outcrop in the area is represented by 57*d* [$\frac{1}{886}$], which occurs on the eastern flank of a low hill about 60 chains east of the 32 M.P. on the Garden Gully Road. Outwardly, it is a rather fine-grained, dark grayish-green rock with a thick red crust. In section, it consists of columnar, platy, and rounded forms of colourless fibrous chloritic serpentine, with opaque gray granular aggregates of a mineral with high refractive index and high birefringence, in the interstices between these forms. The mineral, though somewhat obscure, is referred to granular augite. There are, moreover, some very irregular, pale yellow patches of an isotropic chlorite. The original minerals of the serpentine have been in part pyroxene, in part olivine, the latter being still indicated by the rounded forms. Many of the columnar forms preserve almost crystalline boundaries. An approach to poecilitic structure is shown by the partial moulding of rounded pseudomorphs after olivine by granular augite. The outline of many of the forms

is shown by strings of magnetite and perhaps chromite. The rock appears to have been originally of the nature of a hartzburgite.

Due south of [$\frac{1}{886}$], on the western margin of the uralitised dolerite 54*d* [$\frac{1}{879}$], a serpentine represented by 55*d* [$\frac{1}{799}$] makes its appearance.

In the mass, this rock is very similar in appearance to [$\frac{1}{886}$], In section, it is distinctly coarse in grain, and consists of numerous round forms of serpentine often poecilitically enclosed in intensely fibrous or schillerised anhedral plates of a gray pyroxene, which is in most cases monoclinic. In many of the pyroxene forms, a change to scaly chloritic serpentine is in process. In some cases, the poecilitic structure is remarkably clearly shown, several rounded serpentinised olivines occurring in the augite plates (Fig. 78).

Fig. 78.

Photo : R. A. F. Neg. 1228.

Microphotograph [$\frac{1}{799}$].—The rounded serpentinised olivine grains and the fibrous or schillerised chloritic pyroxene are visible. Poecilitic structure is also, though indistinctly, shown.

Besides the rounded forms, which sometimes occur in patches, there are frequent columnar and platy forms which are broken up by strings and grains of black iron ore, the serpentinous fibres, as usual, being often at right angles to the strings. Many of the pyroxene forms are now obscure, opaque, gray, and granular, from decomposition and development of granular magnetite.

The original minerals in the rock were, therefore, olivine in round grains and platy pyroxene, diallage and possibly in part enstatite. It is essentially identical with [$\frac{1}{886}$].

On the western margin of the same series of uralitised dolerites, serpentine has been discovered, represented by [$\frac{1}{307}$] and 51d [$\frac{1}{888}$]. The former [$\frac{1}{307}$] was obtained from a spot 10 chains north of the 31 M.P. on the Garden Gully Road, and the latter, 57d, from a little distance to the south.

[$\frac{1}{307}$] is a fine-grained greenish-black rock, soft enough to be scratched with a knife. In ordinary light, sections show a colourless mass with small patches of very faint green tint, in which are small threads, squares, and granular aggregates of magnetite, and occasional patches of grayish granular carbonate. In polarised light, there are patches of irregular platy shapes of fibrous serpentine ; a few small patches of talcose scales ; ragged aggregates of calcite grains and some isotropic aggregates of chlorite scales. There is no characteristic form from which the origin of the serpentine can be inferred. The rounded form of olivine grains is not apparent, the structure being rather platy than otherwise. The rock is a chloritic-carbonate-serpentine.

51d [$\frac{1}{888}$], which is a very fine-grained greenish black rock, has in section in ordinary light, a prevailing green tint, and consists of rounded forms of varying sizes, columnar and squarish forms. All the forms in places are in part gray and minutely fibrous, while occasionally there is an opaque, yellowish or brownish, minutely fibrous chloritic aggregate in which, however, rounded cracked forms are also visible. Columnar green plates are often broken up by cracks which are marked by the gray fibrous material. Some of the rounded plates are wholly made up of turbid, yellow, more or less intensely fibrous material. In places, there are some pale pink and slightly pleochroic scales ; in others the forms have quite a crystalline appearance as well defined columns and squares.

In polarised light, the slides are fine scaly with rounded areas of nearly isotropic scaly material and more coarsely scaly columnar forms. In general, however, both the columns and squares and the rounded forms consist of small serpentinous scales. Some anhedral opaque crystals charged with granular magnetite, may represent an original pyroxene, but they are now obscure. Veinlets of talc scales traverse the slides.

The serpentine from near Belele Homestead is fine-grained and black with numerous small brownish ferruginous spots. In section, it is a fine scaly mass with numerous ragged lath-shaped, columnar, and tabular intensely fibrous or schillerised chloritic forms. Some of these, particularly the larger, have an appearance resembling that of lamellated felspars. The fibrous or schiller structure is brought out by a minute dust which marks the striation, gray by transmitted, but brownish-red by incident light. These plates, though obscure in optical characters, may be altered bronzite. Rounded olivine forms appear to be absent, and the rock has thus been derived from a peridotite closely akin to a pyroxenite.

There is one other rock of serpentine character that may be included here*, though on account of the alteration it has undergone, it should, perhaps, more correctly be considered later amongst the Talc-chlorite-carbonate Rocks. Its characters, however, are so distinct, and its origin so clear, that it is considered here. This rock, represented by [$\frac{1}{178}$] occurs in shaft 2, west end of cross-cut, in the Karangahaki Group. It is a dense-black, very fine grained rock. In section, in ordinary light, it is composed almost wholly of small round colourless or faint-green forms, the outlines of which are defined by a ring of magnetite granules. A few thin columnar and irregular forms occur in addition to those rounded. In polarised light, all the forms are seen to consist of minute scales of talc with a little associated chlorite and nearly isotropic serpentine, while besides the ring of magnetite outlining the round crystals, there is frequently a rim of carbonate, which in some cases almost wholly replaces the talc scales. The majority of the rock, therefore, consisted of olivine, so that originally it was allied to a dunite. It is now a talc-carbonate-serpentine (Fig. 79).

Fig. 79.

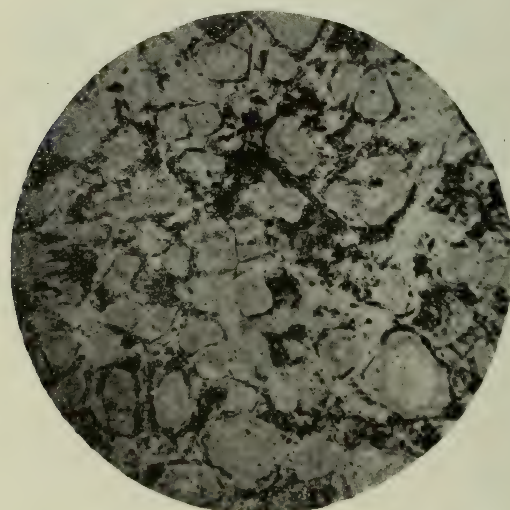


Photo: R. A. F. Neg. 1224.

Microphotograph [$\frac{1}{178}$].—Outlines of olivine grains now pseudomorphed by talc scales. The outlines are defined by magnetite granules.

Relationships and Origin of the Rocks.

It is clear that, on the whole, these serpentines are all closely similar. In the original form of some of them, *e.g.*, [$\frac{1}{178}$] and [$\frac{1}{888}$], olivine appears to have been predominant, in that of others, *e.g.*, [$\frac{1}{799}$]

* The pale green soft chloritic talcose rock extending from the Pioneer main workings to the well of the Government Battery is a talc-chlorite serpentine, but too weathered for description.

and the Belele Homestead rock, pyroxene, if not predominant, was at least very strongly developed. Such variations, however, are just such as might be expected as the result of differentiation in rock masses of the same age and of the same origin from a peridotitic magma. It is particularly worthy of note that these serpentines occur in nearly every case associated with rocks that were once coarse gabbros or dolerites and now are uralitised and zoisitised derivatives of these. Owing, however, to the obscurity of the outcrops in most cases, and to the chemical and dynamical alteration of the rocks in others, it is impossible to state whether the peridotites from which these serpentines have been derived, were separate dykes from the gabbros, or but basic differentiation facies of a gabbroid complex. This constant association, however, of altered gabbro and serpentine is certainly suggestive.

2.—*The Chloritic, Carbonated and Talcose Rocks.*

These have been sub-divided as follows :—

(*a.*) Flecked Schist.
(*b.*) Chloritic Slates.
(*c.*) Black Schists and Black-Talc-Chlorite-Carbonate Rocks.
(*d.*) Flecked Chlorite-Carbonate Rocks.
(*c.*) Fuchsite-Quartz-Carbonate Rocks.

These rocks have all been so much altered by chloritisation, carbonation and talcicisation that their original character has been very considerably disguised or destroyed. In regard to them, it has been felt that to facilitate mapping and to enable the different types to be recognised readily in the field, it is more desirable to describe the rocks under titles which indicate their external appearance and structure than under those which express in technical terms their origin and the changes which they have undergone from their original state, more especially as these rocks are those most closely associated as "country" with the lode formations of the area. Owing, however, to the obscurity of their relations with one another, it has been possible to trace their distribution only by collecting numerous specimens from all available exposures, whether on the surface or in the mine-workings, and by careful microscopic study of vestigial structures and probable former composition. Naturally, by these methods, it is generally quite impossible, from the lack of exposures, to do more than guess at the boundaries of the different facies, and there is frequently a certain amount of doubt even as to what facies are most closely connected, while there is always a difficult balancing of the meagre evidence with regard to the affinities of the specimens with each other. This is especially the case with the talc-chlorite, the flecked chlorite-carbonate, and the fuchsite-quartz-carbonate rocks.

(*a.*) *The Flecked Schists.*—

The type of rock described under this head has been found in the Queen of the Hill Mine at the plat in No. 3 Level. The distribution of the rock is but vaguely known, and is best stated in the words of Mr. Clarke:—"The bulk of the country near Meekatharra is composed of rocks of this subdivision,[1] which form a complex with the peridotitic rocks.[2] The separation of these two types in the field is often difficult, and the boundaries are by no means as definite as would appear from the map."

In external appearance the rock is highly sheared and white with numerous dark green flattened flecks on the shear surfaces. These flecks on the cross fracture appear as extremely thin green streaks or lines. They vary on the flat surfaces from one-eighth of an inch to three-eighths of an inch across in any direction. For some time, owing to the difficulty of obtaining any section of the rock with distinctive characters, it was regarded as tufaceous or agglomeratic in origin, the green flecks being attributed to the flattening out by intense shearing of weathered chloritic fragments or vesicles. Ultimately, however, sections were obtained which proved this view to be erroneous.

Fig. 80.

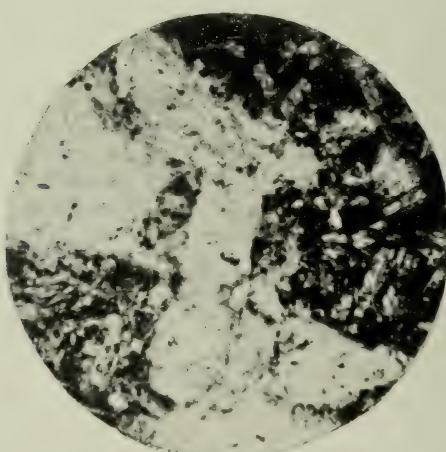


Photo: R. A. F. Neg. 1227.

Microphotograph [$\frac{1}{197}$].—Showing the chloritised phenocrysts of a ferro-magnesian in a fine-grained plexus of felspar laths.

In sections taken from a typical specimen such as [$\frac{1}{197}$], the rock is seen to consist of large, rounded, irregular or columnar forms highly chloritised, in places serpentinised, and seamed

1. He includes the Chloritic Slates in the subdivision.

2. *i.e.*, Black Schists, talc-chlorite-carbonate rocks and fuchsite-quartz-carbonate rocks.

with cracks, in a fine-grained ground-mass which is a plexus of indistinct laths of felspar with associated small chloritic and apparently fibrous hornblendic plates. The large forms are often so sheared and chloritised as to appear as isotropic chloritic fragments with irregular, triangular or wedge shapes. In all sections, the ground-mass is obscured by a large development of opaque, gray granular material, which in some sections is epidote or zoisite, but in most is granular carbonate. (Fig. 80.) Since, moreover, in many sections, the large forms have a triangular, wedge or irregular shape, they suggest enclosed fragments, but slides have been obtained in which an original crystalline phenocrystal habit of these green forms is undoubted, and it is clear from these that the rock was originally a fine-grained doleritic facies with phenocrysts of a ferro-magnesian that was in all probability augite. The structure is sometimes very suggestive of the ophitic.

Two rocks from different localities have been included here, one. represented by 29*d* $[\frac{1}{889}]$, from a crosscut west from Shaft J on (514N), and the other 59*d* $[\frac{1}{890}]$, from a dump in the Ingliston Northern Deeps. Both are extremely weathered, and though they are unlike $[\frac{1}{197}]$, being fine-grained and minutely acicular gray-green rocks, they, nevertheless, both agree with $[\frac{1}{197}]$ in having small dark chloritic forms. But, whereas in $[\frac{1}{197}]$ these forms are green and flattened, and the rock is much sheared, in $[\frac{1}{889}]$ and $[\frac{1}{890}]$ the chloritic spots, which resemble black flint, are nowhere flattened and the rock is unsheared. In section, $[\frac{1}{889}]$ consists of numerous very ragged, small fibrous, greenish, and yellowish chloritic forms, with an indistinct plexus of small rods of felspar in places. Occasionally there are minute greenish scaly patches in which are small spherules of chlorite. There is much brownish iron ore, and apparently some small grains of leucoxene. $[\frac{1}{890}]$ consists of a confused mass of small irregular fibrous plates of chlorite and talc, in an indistinct plexus of small lath-shaped felspars.

Both rocks, therefore, are very similar in character and both are of dolerite origin. Though on the evidence available it is impossible to state definitely what dolerite group they are connected with, from their similiarity to $[\frac{1}{197}]$, and the absence of definite evidence to the contrary, they are included in the Flecked Schists.

(*b.*) *The Chloritic Slates*—

Occasionally, associated with the Flecked Schists, with the Kyarra Schists, and with the Yaloginda Schists, and probably with a considerable development in the Jasper Bar country, are soft, dull, gray-green chloritic slaty rocks, somewhat jointed, and with imperfect fissility. Typical specimens of the rocks—all of which are considerably weathered—are obtainable from the Commodore Mine, *e.g.* $[\frac{1}{199}]$ and $[\frac{1}{200}]$, from the No. 3 Level, crosscut west, near the south end of drive on the West Lode.

These rocks, in section, in ordinary light, consist of a minute, scaly, yellowish, loose ground which at times gives place to pale-yellowish-green chlorite, in which are numerous rounded brownish granular aggregates of iron-stained carbonate, frequently enclosing quartz mosaic or, very rarely, what proves to be in polarised light, minutely lamellated felspar. In addition, there are numerous small black grains probably of iron ore. In polarised light, the yellowish ground becomes almost quite isotropic, with a little minute quartz mosaic. The greenish chlorite is also isotropic.

The origin of these slates is doubtful. While, in structure, they somewhat resemble sedimentary slates, the imperfect fissility, a suggestion of shearing on the cross fracture, the composition largely chloritic and not so heterogeneous as in sedimentary slates, are all characters more in accord with an origin from igneous rocks. An analysis of the rock [$\frac{1}{200}$] made in the Survey Laboratory, gave these results—

	I.	II.
SiO_2	49·22	48·06
Al_2O_3	16·63	16·21
Fe_2O_3	3·00	·89
FeO	6·68	10·37
MgO	7·38	6·67
CaO	2·80	11·37
Na_2O	3·38	2·50
K_2O	0·06	0·27
H_2O + ...	4·90	0·59
H_2O —	1·44	0·10
TiO_2	1·02	·90
CO_2	4·03	1·03
Total	100·54	99·89*

Sp. Gr., 2·65. * Contains ·34 FeS_2; ·59 MnO. Analyst, H. Bowley.

I. [$\frac{1}{200}$].

II. Fine-grained amphibolite, G.S.M. [4425]: Mt. Malcolm, Mt. Margaret G.F. Bull G.S., W.A., No. 11 (1903), p. 7.

Allowing for the difference in the percentage of CaO and CO_2 in the two analyses, there is a noteworthy similarity between them, and the petrological evidence of a derivation of [$\frac{1}{200}$] and [$\frac{1}{199}$] from a fine-grained amphibolite is supported by them.

In the Queen of the Hill, specimens have also been obtained of extremely weathered rocks *e.g.* [$\frac{1}{198}$] and [$\frac{1}{340}$] which are peculiar in both appearance and composition. They are slaty yellowish rocks, brownish yellow in [$\frac{1}{340}$] and pistachio-green and yellow in [$\frac{1}{198}$]. In section, [$\frac{1}{340}$] is a finely foliated slightly contorted chloritic slate with folia of quartz-felspar mosaic. There

is much brown-yellow rutile in grains in the rock. [$\frac{1}{198}$] is in section a fine-grained sericitic phyllitic rock heavily charged with rutile grains and aggregates.

The origin of these rocks is very uncertain. In slaty structure, they somewhat resemble sediments, but [$\frac{1}{340}$], both in section and on the cross fracture, more closely resemble a fine-grained amphibolite. An analysis of [$\frac{1}{198}$] in the Survey Laboratory gave the following results :—

SiO_2	47·21
Al_2O_3	31·27
Fe_2O_3	1·43
FeO	·33
MgO	1·64
CaO	0·14
Na_2O	0·14
K_2O	11·12
H_2O −	0·06
H_2O +	4·37
TiO_2	2·56
Total	100·27

Sp. Gr. 2·86. Analyst, H. Bowley.

The extremely high precentage of alumina and potash is remarkable, and points to a preponderance of a potash alumina silicate, doubtless the sericitic mica. This, with the high percentage of rutile, rather suggests a sedimentary origin of the rock, though the evidence can scarcely be regarded as conclusive.

(c.) *The Black Schists and Black Talc-Chlorite-Carbonate Rocks.*

These rocks are found in mines throughout the Paddy's Flat belt, on the eastern side of the main lode channels from the north end of the Halcyon Group. Their detailed distribution, so far as can at present be made out, is shown in Plate 13. The two varieties frequently occur together and tongues of the Flecked Schist cross the complex of the two, while the Flecked Schist is developed both on the east and on the west side of it. The Black Schists are developed chiefly in the southern portion of the belt, and the Talc-Chlorite-Carbonate rock chiefly in the northern.

The Black Schists.

These are typically developed in the Ingliston Extended Mine, frequently in close contact with the black dolerite.

In hand-specimens they are gray-black to dense black fine-grained rocks, rather soft and frequently sheared, and closely resembling the talc-serpentine of the Karangahaki [$\frac{1}{178}$]. Under the microscope, they generally present a rather remarkable appearance. There are numerous squarish, columnar and rounded clear forms of minute scaly talc in a fine-grained black or brownish-black, frequently minutely fibrous ground. (Fig. 81.) It has

Fig. 81.

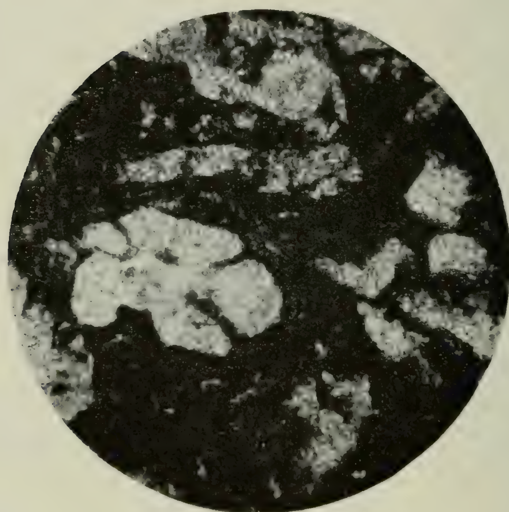


Photo: R. A. F. Neg. 1230.

Microphotograph [$\frac{1}{801}$].—Exhibits the apparent porphyritic character of the rock. The light coloured forms are talc pseudomorphs, the dark areas mostly brownish and blackish chlorite.

been already remarked that near the contact with these schists, the Ingliston Extended dolerite is highly porphyritic with a minute ground-mass. Consequently, at first these rocks were taken as highly altered and somewhat sheared products of this dolerite, the apparently phenocrystal talc forms being regarded as pseudomorphs after felspar. The occurrence, however, of frequent large rounded forms with thin streaks of blackish fibrous material, the similarity of the finely-fibrous ground to the yellowish and brownish finely fibrous chloritic material already described in [$\frac{1}{888}$] and the resemblance between the squarish and columnar forms, and the serpentine

plates in [$\frac{1}{886}$] and other serpentines raised doubts of their genetic connection with the dolerite. Moreover, an analysis of one specimen [$\frac{1}{137}$], from the 425ft. Level, of the Ingliston Extended, gave the following results :—

SiO_2	40·32
Al_2O_3	6·63
Fe_2O_3	3·41
FeO	7·34
MgO	25·66
CaO	4·57
Na_2O	·22
K_2O	Trace
H_2O + ...	7·16
H_2O —	1·32
TiO_2	·64
CO_2	2·78
C	·06
Total	100·11

Sp. Gr. 2·74. Analyst, H. Bowley.

The low percentage of Al_2O_3 and SiO_2, and the extremely low percentage of the alkalies, show that the colourless scaly material of the pseudomorphs is not mica, but talc, while this fact together with the extremely high percentage of MgO indicates clearly that the original rock was an ultrabasic and highly magnesian type.

From both microscopic and chemical evidence, therefore, it is most probable that the rock was originally a serpentine derived from some variety of a peridotite.

The nature of the black ground is difficult to determine, but it consists largely of brownish and blackish chlorite often so minutely fibrous as to resemble an aggregate of microlites. The colour was suspected of being in part due to carbon and the analysis of the rock confirms the suspicion. At times, all trace of the pseudomorphs is lost, and the rock consists entirely of a minute scaly mass of talc. At times, granular carbonate occurs in aggregates or strings, and not infrequently, strings, veinlets and patches of yellowish scaly fibrous material traverse the rock and the slides, material that is referable to a mixture of talc and chlorite. Some ilmenite in small grains is also present as shown by the analysis, though neither ilmenite nor rutile could be identified on account of the general opacity of the slides.

The contact of the rock with the dolerite has already been described.

Fig. 82.

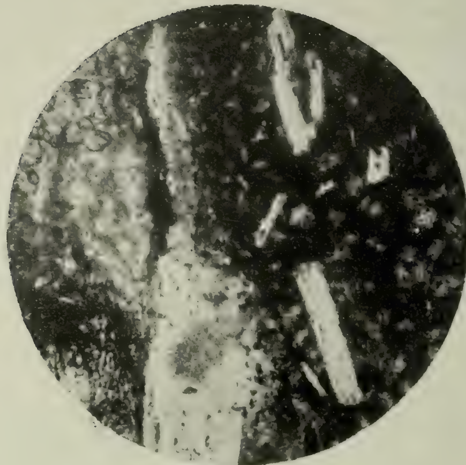


Photo: R. A. F. Neg. 1225.

Microphotograph [$\frac{1}{802}$].—A view of the junction between the dolerite and the black schist. The former is a porphyritic andesitic facies, and the junction is marked by a black band probably of graphitic material.

The Black Talc-Chlorite-Carbonate Rocks.

These are greenish-black, soft, brittle, talcose rocks frequently sheared, though sometimes massive, with small euhedra of magnesian carbonate. In some specimens there are large patches of a pale-green carbonate, and in others, occasional rounded aphanitic black chloritic forms which resemble black vesicular fillings. Typical specimens are 499*c* [$\frac{1}{891}$] and 492*c* [$\frac{1}{892}$] from the main shaft of the Macquarie Lease.

The former, [$\frac{1}{891}$], in section, consists of numerous small white rounded forms, made up of talc scales, surrounded by a yellowish green ground of chloritic scales and scaly aggregates occasionally almost isotropic. The talc forms are of various shapes, rounded, partly sharp-edged with almost crystalline boundaries, frequently cracked with chloritic scales along the cracks, zoned by yellowish chloritic material, and, in some cases, with the middle occupied by chlorite and with scaly talc on the outside. At times, the round talc forms seem poecilitically enclosed in the chlorite. (Fig. 83).

The mineral composition and structure of the rock in section prove it to be with little doubt derived from an olivine-peridotite in which the olivine grains have been altered to talc, and the ferromagnesian to chlorite. The large, rounded, black patches, however, are difficult to account for. These, in section, are of various

shapes and composed of yellowish minutely scaly chlorite often with a rim of carbonate or talc. At first they were regarded as chlorite infillings of vesicles, but the structure of the rock is not that of a vesicular type, and, though serpentines are known to be derived in some cases from eruptive rocks, the structure is not by any means that of an eruptive. Their occurrence suggests either the presence of original large crystals now completely broken down into chlorite, carbonate, talc, or a mixture of these, or differential alterations of portions of the rock mass.

Fig. 83.

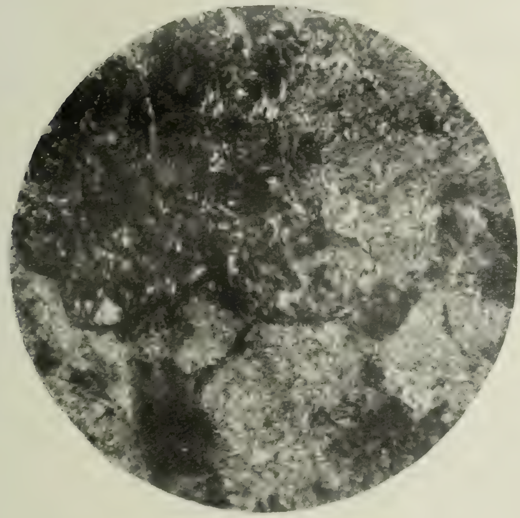


Photo: R. A. F. Neg. 1233.

Microphotograph [$\frac{1}{803}$].—The darker areas are of fibrous serpentinous chlorite, the lighter areas of pearly talc scales.

A large number of specimens referred to this group, show considerable variation in character. Some are without the aphanitic black patches and consist of a pale-greenish, fine, scaly, talc-chlorite mass, in which occur numerous euhedra of carbonate, scattered strings, rods, and loose aggregates of rutile needles and grains (Fig. 84). Others consist of a mass of talc scales with granular carbonate, sometimes with apparent columnar carbonated pseudomorphs and ragged pale-green chloritic patches with 'blue' interference colour, and with columnar platy and rounded talc forms as in [$\frac{1}{886}$]. The pale-green, soft, chloritic-talcose rock extending from south of Savage's workings to the Well of the Government Battery is considered a variety of the Black Talc-Chlorite-Carbonate Rocks (*see* Plate 4).

Certain extremely weathered rocks mostly of doubtful origin, have been included in the group. Among these are rocks such as $[\frac{1}{201}]$ from the Reward Lease, New Orleans Group, Shaft 7. They are yellow-green clayey rocks with numerous small irregular patches of aphanitic material in an apparently finely fibrous mass. Since in external appearance they rather resemble breccias, they have been referred to in the description of the Mines as ' Pseudo-breccias.' Owing to the decomposed nature of $[\frac{1}{201}]$, it has been found extremely difficult to obtain sections of any value, but by special treatment of the rock with balsam, the difficulties were to a certain extent overcome. Sections prepared in this manner show the rock to consist of yellowish scaly chlorite enclosing long columnar

Fig. 84.

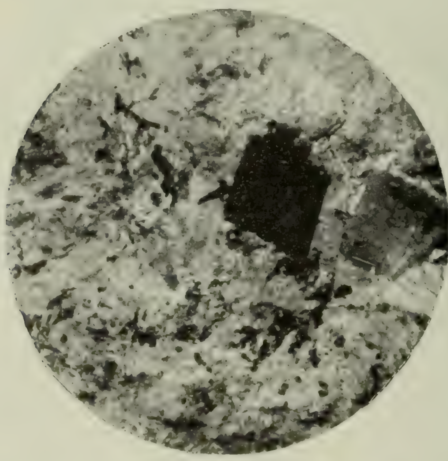


Photo : R. A. F. Neg. 1234.

Microphotograph $[\frac{1}{201}]$.—A fine-grained mass of talc scales with a little chlorite and crystals of carbonate.

chloritic forms which, in a general way, resemble the felspar colmuns of dolerites, but from which the optical characters of felspar are absent. Enclosed also are large fine scaly patches of chlorite, which represent the aphanitic fragmental or xenolithic forms.

The origin of the rock is obscure. Certainly the yellowish ground with the chloritised columnar forms resembles that of a highly weathered chloritised dolerite, and in Plate 4, the rock is seen to be in close proximity to the Flecked Schist which, as already stated, is a chloritised porphyritic dolerite. On the other hand, the appearance of some sections resembles that of rocks to which a peridotitic origin is ascribable, *e.g.* $[\frac{1}{190}]$ which will be described immediately, and the large irregular chloritic patches are scarcely

such as would be expected in a dolerite even much decomposed, while they to some extent resemble the black patches in such rocks as 499c.

Though the rocks however, have been included amongst those of peridotitic origin, what little evidence they afford is equally indicative of an origin from doleritic rocks. The large xenolithic patches may have been the result of differential weathering of the constituents of the original rock due to slight difference in chemical composition—and hence they may have been large ferro-magnesian crystals—or they may represent vesicles, though their appearance in section hardly supports an origin from vesicles. It is noticeable that in the chloritic ground there are many small chloritic areas closely resembling the larger patches, and it is possible that there is a connection between these rocks and rocks such as [$\frac{1}{889}$] and [$\frac{1}{890}$].

Again, another much weathered rock included in the group is that represented by [$\frac{1}{205}$] from the Gwalia Extended Leases, Shaft C. This is a very decomposed, massive, dull greyish-green rock in which numerous small greenish-black fragmental chloritic forms can easily be distinguished. All specimens obtained show a large development of yellowish carbonate in small crystals.

In Section [$\frac{1}{205}$] consists of a mass of ragged, platy, talcose and pale-green chloritic forms with crystals of a carbonate in the chlorite patches, and aggregates of carbonate in various parts of the slide. Associated with some of the talc and chlorite aggregates and plates are small aggregates and strings of brown-yellow rutile needles and grains. Occasionally there are ragged large patches of nearly isotropic, fine scaly chlorite, which form the fragments visible in hand specimens. In the talcose areas are grains and granular aggregates of black iron ore. Traces of original structure are almost wholly absent, but as the structure is platy and the composition obviously basic and highly magnesian, the rock has been considered as originally of peridotitic origin. The chloritic 'fragments' which give the rock a tufaceous appearance may have the same origin as those [$\frac{1}{201}$].

From the Queen of the Hill Leases, again, Shaft B, 105ft. Level, an extremely weathered grayish-green rock of nondescript appearance, represented by [$\frac{1}{190}$], has been obtained. After much difficulty, and only after treatment with balsam was a section cut from it. This showed the rock to consist of rounded white or greenish-white forms with the interior occupied by granular iron ore, and yellow-green patches, columnar forms and squarish plates of chlorite and large, irregular patches of a yellow-green fine scaly mixture of talc and chlorite, resembling, except for the presence of talc, the areas in [$\frac{1}{201}$] and to some extent, the chloritic forms in [$\frac{1}{891}$]. The structure is doubtful, but appears to be platy or granular, and similar to that of [$\frac{1}{205}$]. Moreover, there are ragged flakes charged with rutile grains and needles as in [$\frac{1}{205}$]. The

origin of the rock is indefinite, but there is evidence in its structure and probable composition for regarding it as an altered peridotite or serpentine. It is now apparently a chloritic talcose serpentine.

Finally, in the Marmont G.M., 145ft. Level, end of west cross-cut at the south end of the Mine, some brownish-gray clayey rocks represented by 1*d*—4*d* [$\frac{1}{893}$], were discovered. These are characterised by the presence of numerous deep-green rounded aphanitic, chloritic forms and numerous small brownish-yellow crystals of a carbonate in a soft talcose-chloritic ground or mass. Being little better than clays, they are extremely difficult to section, but the sections prepared show small ovoid or rounded talcose forms, surrounded by a brownish-red or yellow-stained chloritic mass, which, in very thin sections, is seen to be made up of minute scaly chlorite. There are, also, occasional euhedra and grains of a carbonate partially oxidised to ferric oxide. Moreover, there are numerous scaly, greenish forms rounded and bluntly angular, which appear as xenoliths, but are composed of minute, scaly and fibrous greenish chlorite. As in the case of other pseudo-fragmental rocks, there were at first supposed to be a tuff, xenolithic or vesicular rock, but the little that can be made of the composition and structure agrees more closely with a fine-grained talc-chlorite-carbonate serpentine. In some sections, there are occasional clear secondary felspar forms as in 421*c* [$\frac{1}{894}$], while in others, the fine scaly xenolithic forms appear to pass into similar small ones in the ground.

(*d.*) *Flecked Chlorite-Carbonate Rocks.*

These rocks, so far as can be discovered, are developed only in the Commodore Mine. In the mass, they are grayish-green, highly sheared with marked flecks of greenish-black chlorite on the shear surfaces, and heavily carbonated as shown by numerous small, brown-red crystals of a ferriferous species. The rocks are typically represented by [$\frac{1}{204}$] and [$\frac{1}{146}$]. [$\frac{1}{204}$], from the Commodore No. 3 Level, north end of drive on the West Lode, consists in section, and in ordinary light, of a pale-green chloritic mass in which are ragged plates of carbonate in some cases unaltered, in others partially altered to a brownish or yellowish oxide of iron, and occasional ragged grains of black iron ore. A few rounded colourless plates occur in the chloritic patches, and the latter also enclose minute grains and needles of brown-yellow rutile. In polarized light, the slides show large ragged plates of carbonate, and ragged patches of nearly isotropic chlorite in a ground which consists of small ragged plates and indistinct small columns of a colourless mineral interspersed and interrupted by isotropic chlorite scales. The colourless plates are difficult to identify, but undoubtedly appear to be partially composed of felspar. Occasional indistinct, columnar, partially chloritised columns appear closely resembling columnar felspars, and in several instances there is a suggestion of albite lamellation in the forms. The general appearance of the

ground is that of short columns or laths of felspar broken down into small plates, and partially obscured by small scales of nearly isotropic chlorite. In some cases, apparently, the lamellation is caused by strings of isotropic chlorite alternating with colourless rods. Enclosed in the ragged chloritic patches or flakes, are rounded, colourless plates, generally broken down into a mosaic, of which quartz appears to be the main constituent. Allowing for the disintegration of the felspathic laths, the appearance presented by the chloritic patches and the ground strongly suggests the the structure of the Flecked Schists $[\frac{1}{197}]$. An analysis of $[\frac{1}{204}]$, made in the Survey Laboratory, gave these results :—

SiO_2	36·75
Al_2O_3	21·05*
Fe_2O_3	1·25
FeO	7·60
MgO	8·82
CaO	6·88
Na_2O	0·25
K_2O	0·08
H_2O +	6·98
H_2O	0·32
TiO_2	0·11
CO_2	10·48
Total	100·57

* Includes P_2O_5 and MnO. Analyst, H. Bowley.

Especially worthy of note in the analysis is the extremely high percentage of Al_2O_3. The very low percentage of alkalies indicates that the alumina can be present only in very small amount as a felspar. Undoubtedly there is a considerable amount of chlorite in the sections, but it is doubtful whether the chlorite and albite combined are sufficient to account for such a high percentage of alumina. No aluminous silicate, however, other than those noted, could be identified in the sections examined.

$[\frac{1}{146}]$ from the No. 4 Level, north end of the same mine, is essentially the same as $[\frac{1}{204}]$, but is dark-gray in colour and more heavily carbonated.

The origin of these rocks is again obscure. The resemblance between their structure and composition to those of the Flecked Schists has just previously been noted. Further, from their basic nature, a derivation from a peridotitic facies is possible. The extremely high percentage of alumina, however, would be phenomenal in rocks which are typically characterised by a very low percentage of this constituent. Furthermore, the amount of magnesia present is extremely low for such rocks. Owing to the extreme degree of chemical and dynamical alteration of the rocks, evidence of their origin is very meagre, but both in structure and composition they appear more closely allied to the Flecked Schists $[\frac{1}{197}]$, than to any other type.

(*e.*) *The Fuchsite-Quartz-Carbonate Rocks* :—

The detailed distribution of these rocks will best be understood by reference to Plate 4. Broadly speaking, however, they have been obtained in the following localities :

In the Commodore Mine, the Flecked Carbonate-Chlorite rocks appear to pass into highly carbonated rocks characterised by the presence of small emerald-green scaly patches. In the curving belt mapped from the Commodore to the north end of the Ingliston United Lease, rocks have been mapped which, though much weathered, have certain similarities with the emerald green carbonates from other mines.

Relatively small patches have been discovered bordering on the porphyry in the Ingliston Extended workings, in the Ingliston Consols and in the Fenian Mines. A large belt has been mapped, though mostly again on weathered specimens, extending from the latter to the south end of the Paddy's Flat Belt.

Finally, fuchsitic carbonate rocks occur at the Globe.

With the doubtful exception of the Commodore Mine, in all the localities the relationship of the rocks to the surrounding country is indistinct, and even in the Commodore, the passage of the Flecked Carbonate-chlorite rocks into the Fuchsite carbonate rocks is by no means clear.

The chief characters of the typical fuchsitic rocks have already been described in a previous Bulletin[1], so that only a brief account need be given here. In hand specimens, they are crystalline carbonate rocks generally of medium grain and of an emerald-green colour, often with veinlets of quartz or of a magnesian carbonate. There are, however, variations in grain and colour. Some varieties are very coarsely grained, others have comparatively little fuchsite present and are of a gray colour. In some, the crystalline carbonate appears of a yellow colour indicating a ferriferous species. Typical specimens in section are fine granular, extremely carbonated rocks with the carbonate in numerous small plates, with many mostly colourless flakes and scaly aggregates of pale green fuchsitic mica. There are frequently veinlets of fluidal quartz and albite, while all over the sections are small acicular and opaque granular aggregates, yellow by incident light and passing at the margins into needles of brown-yellow rutile. In some cases, there are black granules in the fuchsitic areas, which may be chromite, though it is impossible to identify them.

Origin of the Rocks.

In a previous publication, the writer has discussed this difficult question, and, though basing his remarks on the examination of a very few specimens and on observations in the mines of very

1. Bulletin 43, G.S.W.A.

limited duration, came to the conclusion that they were probably derived from rocks of peridotitic character. For the present survey, considerably more careful and extensive field observations have been made, and a greater number of specimens have been examined, but little additional evidence of a decisive nature has come to light. Some specimens, however, with characters rather different from the normal green rock have been discovered, and, from the point of view of the origin of the rocks, these merit brief description. [$\frac{1}{147}$] from the No. 4 Level, Commodore Mine, near the north end, both in hand specimens and in sections closely resembles [$\frac{1}{146}$] which is included amongst the Flecked Chlorite-Carbonate rocks. It is fuchsitic, sheared, and slightly flecked, and characterised again by small opaque granular aggregates, yellowish by incident light, which give rise to minute needles of rutile. [$\frac{1}{805}$], 66d also closely resembles [$\frac{1}{146}$]. In it there are large ragged flakes

Fig. 85.

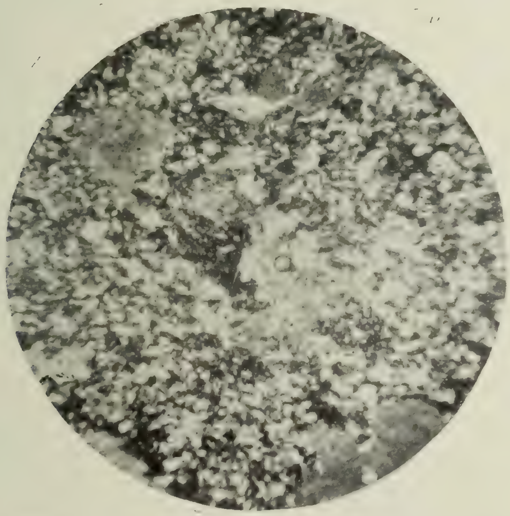


Photo: R. A. F. Neg. 1226.

Microphotograph [$\frac{1}{805}$].—Showing the minutely platy, largely felspathic mass in which are plates of carbonate and irregular areas of isotropic chlorite.

of nearly isotropic chlorite and large plates of carbonate in a fine-grained ground consisting of minute clear plates and indistinct partially disintegrated laths of felspar. (Fig. 85). This passes into a variety in which irregular platy carbonate is predominant with small areas of quartz mosaic and small plates of quartz. The chloritic flakes are charged with minute needles of rutile, and both

the carbonate and chlorite, and the fine-grained ground are scattered over with small opaque granular aggregates as in $[\frac{1}{147}]$. $[\frac{1}{142}]$ is very similar to $[\frac{1}{805}]$. On the other hand, 336c, which is a crystalline limestone with fuchsite and yellowish ferriferous carbonate, somewhat resembles the Talc-Chlorite-Carbonate rocks, *e.g.*, $[\frac{1}{187}]$, that have probably been derived from serpentines or peridotites. Moreover, it is worthy of note that, in the Yukon District of Canada[1], east of the Big Salmon River, fuchsite scales with quartz and chromite grains have been found associated with magnesite that has probably been derived from peridotitic rocks[2], and at the mouth of the Hunter Creek, Klondike River, in the same district, fuchsite scales are associated with white dolomite[3].

The Fuchsite-Quartz-Carbonate rocks, therefore, are closely akin, on the one hand, to the Flecked Chlorite-Carbonate rocks, and, on the other, to the Talc-Chlorite-Carbonate rocks, to which a peridotitic origin has been assigned. Owing to the extreme chemical alteration, however, of the rocks, and the obscurity of their field relations, evidence of their origin is still very meagre and inconclusive; but there is reason for regarding them as more probably derived from the original of the Flecked Carbonate-Chlorite Group than from rocks more clearly of peridotitic origin. The fact that in many cases the fuchsite appears more strongly developed along cracks, joints, and near the margins of the rocks, and that some varieties contain very little fuchsite, suggests that the chromium content may not be original, but may have been introduced by solutions, and hence, by eliminating the necessity for explaining the presence of chromium by the chemical alteration of chromite in the rocks, renders a derivation from the original form of the Flecked Carbonate rocks less unlikely.

B.—*Volcanic or Eruptive in Origin.*

Immediately east and south-east of the Paddy's Flat Belt, extending in a narrow band from near the Globe G.M. to the neighbourhood of the Macquarie Lease, a generally well-marked series of a distinct volcanic character is found outcropping. As with other series, however, owing to the occurrence of the rocks only as outcrops and mostly, if not wholly, on a fairly flat surface that has been generally very considerably weathered, and that is frequently covered with several feet of overburden, it has been found impossible to map the boundaries of the rocks, or to do otherwise than merely indicate their position. Consequently, though in the volcanic series, as will be seen later, several types and varieties are represented these have all been grouped together and indicated by the same colour and symbol.

1. *Vide* "A List of Canadian Mineral occurrences, by R. A. A. Johnston; G.S.C., No. 61, Geological Series, p. 99.
2. Loc. cit., p. 99.
3. Loc. cit., p. 99.

Briefly, the series has been found to consist of volcanic agglomerates or tuffs, crystal-tuffs, and volcanic flows, which comprise augite-andesitic rocks, and very fine-grained weathered basaltic rocks, exhibiting in some specimens small spheroids that probably indicate a vesicular structure. Some doubtful extremely weathered rocks have also been included in the series.

The Tuffs or Agglomerates, and Crystal Tuffs.

The former are dark green in colour and consist of an agglomeration of numerous more or less equi-dimensional rounded and angular aphanitic fragments usually about ¼ inch to ⅜ inch across. On a fresh fracture, there is not the uneven surface of many breccias and conglomerates, due to the component forms projecting from the surface, but a roughly plane pavement in which the fragments give a mosaic appearance. Specimens of this nature grade into rocks to which the name crystal tuffs has been ascribed. The latter, which are mostly very dark gray or nearly black in colour, and so fine-grained as to appear flinty, consist to the naked eye of lenticular, triangular, and irregularly outlined patches, differing somewhat in tint, in a flinty ground, in which at times a considerable number of small, squarish and rectangular crystals of a white felspar are visible. Some specimens are light-gray in colour with the fragmental forms very indistinct. The enclosed fragments in general are finer in grain and more flinty than the ground, and in some instances are light gray or brown in tone and quite an inch across. There are occasional lenticular vesicular patches with a white flinty border enclosing quartz.

(a) *The Tuffs.*

The microscopic character of the more fragmental rocks or those that have been called the Tuffs is illustrated by [**11205**] from 20 chains E. of G.M.L. 888x, Mickey Doolan. This, in section consists of numerous large and small irregularly banded platy forms of pinkish and opaque-gray isotropic glassy material, with frequent pale-green plates of various shapes, which, from the blue interference colours in polarised light, are at least in part, a chlorite, though in some forms, wholly isotropic, probably a glass. The spaces between the larger plates are occupied by smaller similarly shaped forms, amongst which are also small plates and grains of a carbonate (calcite). Decomposition in many of these larger glassy forms has resulted in the production of small patches of isotropic chlorite, some granular carbonate, and, associated with the chlorite, numerous small grains of epidote. A few of the larger glass fragments are now represented wholly by granular carbonate and intermixed isotropic glassy patches; others show an approach

to a microlitic structure, having rare small phenocrystal laths of felspar in a minutely microlitic ground-mass; some consist, wholly or in part, of a mass of minute highly birefringent granules referred to epidote, and others, again, are either quite aphanitic, opaque and dense white by incident light, or consist of cryptocrystalline almost isotropic flinty material. There are, further, rare crystals of fresh, colourless and pinkish augite and of untwinned felspar. In some of the brown glass fragments there is an indistinct streaky structure. The cementing material, of which there is, however, very little, is calcite.

One of the most noteworthy and important features is the fact that, in addition to the glassy and chloritic forms, there are occasional fragments of fresh rocks. These have been found to consist:—

(a) Of granular, fresh, pinkish-gray augite with somewhat obscure laths of felspar and with indistinct ophitic structure.

(b) Of augite grains and felspar laths with clear ophitic structure. These fragments closely resemble $\left[\frac{1}{334}\right]$ in structure.

(c) Of fragments similar to the above in which, however, a decidedly fibrous character has been induced in the ferro-magnesian. The fibrosity subsists sometimes all through the fragment, sometimes only on the margins in contact with the glassy forms, the interior still consisting of granular augite.

(d) Of fragments in which the ferro-magnesian is so intensely fibrous as to ally them with such forms already described in $\left[\frac{1}{346}\right]$ and $\left[\frac{1}{302}\right]$.

(e) Of granular grayish-pink augite in an apparently glassy mass, in which some obscure small laths of felspar can also be seen as well as small plates of quartz.

The significance of these rock enclosures is that from a study of them it would appear that while the age of the tuffs cannot yet be arrived at with any degree of accuracy, their formation at any rate post-dates the solidification and fibration of such dolerites as $\left[\frac{1}{334}\right]$ and of the fine-grained amphibolites of the type of $\left[\frac{1}{302}\right]$. Moreover the complete absence of any black fragments resembling the Ingliston Extended dolerite, in conjunction with the fact that the structure of the enclosed doleritic fragments agrees rather more closely with that of such rocks as $\left[\frac{1}{334}\right]$ and $\left[\frac{1}{302}\right]$ tends to show that the intrusion of this dyke itself post-dates the formation of the tuffs.

An analysis of the agglomerate [11205] made in the Survey Laboratory gave these results:—

SiO_2	45.56
Al_2O_3	19.95*
Fe_2O_3	2.40
FeO	10.61
MgO	1.74
CaO	7.59
Na_2O	1.72
K_2O	2.16
H_2O —	.11
H_2O +	4.49
TiO_2	.69
CO_2	2.82
C	trace †
Total	99.84

Sp. gr. 2.87. Analyst, H. Bowley.

Interesting features of this analysis are the large percentage of alumina and the apparent excess of potash over soda among the

Fig. 86.

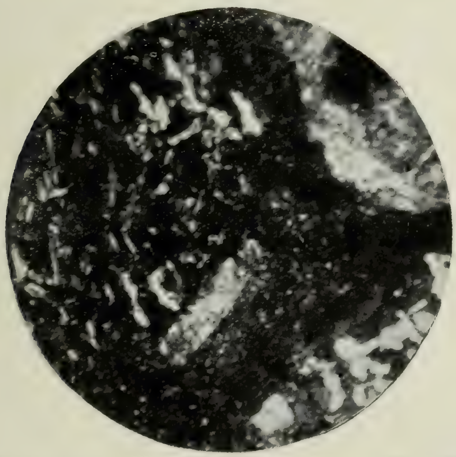


Photo: R. A. F. Neg. 1232.

Microphotograph [$\frac{1}{503}$].—Exhibits an andesitic fragment in an almost isotropic mass with occasional felspar phenocrysts.

alkalies. In chemical composition, then, as in mineral constitution, the rock is a distinctly basic facies and appears more closely related to basaltic than to andesitic agglomerates.

* Includes MnO and P_2O_5. † Probably as graphite.

(b) *The Crystal Agglomerates or Crystal Tuffs.*

The specimens described under this head seem to be intermediate between the agglomerates proper and a glassy porphyritic rock. The various fragments decidedly resemble xenoliths in a fine-grained ground, and indeed, in origin they are not markedly different from these enclosures in igneous rocks. The chief characters are exhibited in $\left[\frac{1}{203}\right]$ from about half a mile south of the Gwalia Extended shafts (Fig. 86). Under the microscope, there is a porphyritic matrix or ground containing numerous fragments of various character. This ground is made up of occasional rather small columnar and squarish phenocrysts of cloudy felspar in an almost isotropic cryptocrystalline glassy mass. Enclosed in the latter, in addition to the felspars are the xenolithic fragments. These are both large and small and of the following types:—

(a) Partially chloritic, wholly isotropic ragged glassy fragments with scattered small aggregates of epidote grains and a streaky structure.

(b) Angular fragments of opaque gray material which in polarised light consists of a felt of thin laths of felspar with distinct flow arrangement of the laths. These closely resemble fragments of trachytic andesite.

(c) Fragments very similar to the above but with the laths fewer in number and broader, and with the structure less dense. There are small, clear platy forms in addition to the laths.

(d) Others somewhat similar to (c), but with the felspar laths forming a plexus. As in (c), felspar laths form almost the whole of the fragment.

(e) Others ellipsoidal in shape, almost wholly isotropic with obscure remains of felspar laths, and containing opaque, gray, granular, rounded plates which in polarised light resemble turbid felspars.

(f) Isotropic lenticular patches of green chlorite.

(g) Various irregular glassy fragments almost quite isotropic, with enclosed small patches of green chlorite, and obscurely microlitic.

(h) Various irregular streaks resembling "schlieren," with marked flow arrangement of small laths of felspar, and with disseminated gray granular epidotic and zoisitic material.

(i) Occasional slightly chloritised crystals of augite and grains of calcite.

The largest fragments show a flow structure in minute microlitic laths of felspar with occasional felspar phenocrysts, and, in addition, small lenticular patches composed of a plexus of felspar laths, which themselves appear as included fragments.

It will be seen, therefore, that these component rock fragments differ more or less from each other; the prevailing facies among them closely resembles a fine-grained trachytic andesite.

Varieties grading into the augite-andesitic flow of the succeeding section are represented by **13d** $[\frac{1}{895}]$. This is a yellowish-grey, fine-grained rock in which fragmental structure is not visible. In section, there are numerous opaque minutely grained glassy patches with obscure microlitic structure and with phenocrysts of augite and altered felspar and patches resembling portions of **16d**[1] $[\frac{1}{896}]$ punctuated by small areas of irregular shape of cryptocrystalline mosaic. There are also aggregates of small patches of cryptocrystalline mosaic rimmed by strings of isotropic material and associated with numerous plates and some crystals of augite. A few small thin lenticular areas with minute mosaic round a green string of minute chlorite scales may represent vesicles.

The Flow Rocks.

Though the specimens included in this section do not for reasons already given afford evidence of volcanic origin in the field, they show characters in section which warrant such an origin being ascribed to them. Owing, however, to the much weathered state of some of the specimens, especially **31d**, $[\frac{1}{897}]$ $[\frac{1}{359}]$ and **94d**, $[\frac{1}{898}]$ to the fact that only isolated outcrops of the rocks can be obtained, and to the impossibility in practice of ascertaining the nature of the country between the various outcrops, it has not been found possible to trace their realation to one another. It may, indeed, ultimately be found that they are not all of the same origin or age, but as, on the evidence at present afforded, no clear division on these bases can be made, they must be considered for the time being and until fresher outcrops are obtainable merely as a volcanic group. Nevertheless, from the point of view of structure and mineral composition, it is possible to arrange the rocks under the following heads:—

(a) The augite-andesitic type with flow structure.
(b) Doubtful varieties of (a) extremely weathered.
(c) The fine-grained basaltic rocks.
(d) Other very doubtful dolerite flows.

(a) The augite-andesitic flow:

This is typically represented by **16d** $[\frac{1}{896}]$, from about 1¼ miles S.E. of the S.E. corner of the Gwalia Extended (G.M.L. 872N). In hand specimens, the rock is a very fine-grained dull-green flinty facies with occasional small dull phenocrysts of felspar and a red crust. Sections are extremely dense, and hence somewhat obscure,

1. See later.

but there are well-marked phenocrysts of colourless augite sometimes carbonated, chloritised, or epidotised, and phenocrysts of turbid felspar, in a fine-grained ground-mass of innumerable small laths of felspar with distinct flow structure. The laths frequently curve in gentle folds round the phenocrysts. The ground-mass is so dense and generally of such low birefringence as to suggest the presence of a residuum of glass. Opaque yellowish granular material (epidote ?) occurs scattered all over the ground. The structure of the rock, more or less trachytic, is almost identical with that of several of the included fragments in the crystal tuffs (Fig. 87). In places,

Fig. 87.

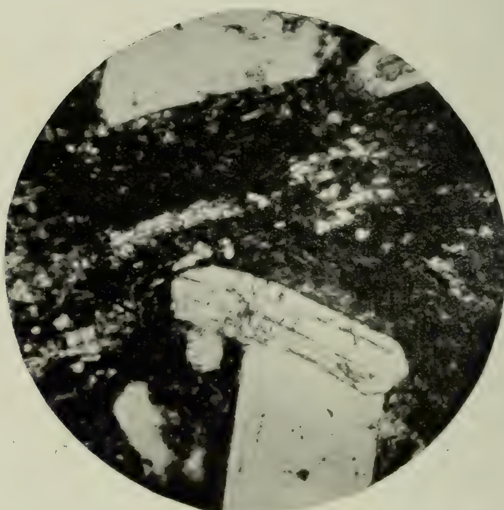


Photo: R. A. F. Neg. 1238.

Microphotograph [$\frac{1}{800}$].—Showing phenocrysts of augite in a minute ground-mass in which flow structure is indistinctly visible.

there are rounded and very elongated patches consisting of minutely crystalline mosaic enclosing strings of pale-green, nearly isotropic chloritic material, which probably represent vesicles.

There is a strong resemblance between [**11205**] and [$\frac{1}{203}$] on the one hand, and between [$\frac{1}{203}$] and [$\frac{1}{896}$[on the other, and there seems little doubt of a close connection both in chemical and mineral composition and time of eruption of all these. Moreover, there is reason for believing that agglomeratic rocks not markedly different from those at Meekatharra have a fairly wide distribution in the State. As will be seen later, fragments similar to those in [$\frac{1}{203}$] occur in the tufaceous arkose of Mt. Yagahong. There is a close resemblance between these fragments and those in the matrix of a

conglomerate near Lake Raeside,[1] Yilgangi. Moreover the agglomerate itself is in many ways akin to the volcanic breccia [13983] from five miles south of Survey Station C.C. 121.[2] Finally, at Mt. Singleton,[3] green tuffs or ashes have recently been discovered which are not markedly different from the Meekatharra agglomerate.

(b) *Doubtful weathered varieties of* (a).

Certain extremely weathered brick-red ferruginous rocks of which **65d** [$\frac{1}{899}$] is an example present characters somewhat allied to those of [$\frac{1}{896}$] and they perhaps represent an extension of the volcanic belt. In [$\frac{1}{899}$] from the Macquarrie G.M. South shaft, there are large phenocrystal talcicised and sericitised forms in a comparatively coarse plexus of indistinct felspar column. The talc pseudomorphs probably represent phenocrysts of augite. A large amount of brownish-yellow granular ferruginous material obscures the sections, and amongst it are grains which, being greyish-white in incident light, may be leucoxene. A little seemingly interstitial quartz is visible in places.

The rock has a porphyritic doleritic structure that suggests affinities both with [$\frac{1}{896}$] and with the Ingliston Extended dolerite.

In other specimens, however, from the Macquarrie, there are large circular, concentric vesicular forms in a red, highly ferruginous mass, while **63d** [$\frac{1}{900}$] also from the same locality, is a fine-grained porphyritic rock with a fine-grained ground-mass and no distinct traces of doleritic structure.

A much weathered rock, of which **25d** [$\frac{1}{901}$] is a specimen, occurs in a shaft on a knoll about half a mile east of the Fenian G.M. Its characters are inconclusive, but since it shows in section traces of large apparently phenocrystal forms, all highly ferruginous, in a fine-grained red iron-stained obscure ground-mass, it has been, in default of evidence of other affinities, included in this group.

(c) *The Fine-grained Basaltic Rocks.*

Two outcrops of these have been discovered, one, represented by [$\frac{1}{359}$] about a quarter of a mile north of the Globe G.M. in a small creek, and the other, represented by **90d** [$\frac{1}{902}$] and **94d** [$\frac{1}{898}$] from No. 2 shaft, about 300 feet E.S.E. of the Ingliston Extended East (G.M.L. 462N), 100ft. level, middle of East crosscut. [$\frac{1}{359}$] is a minutely grained yellowish compact clay which, in section, consists of a ground-mass of very small rods of felspar separated by yellow scales of chloritic and clayey material and some grains of yellow epidote. The scales appear to have been derived from augite.

1, 2, 3. The petrology of these outcrops is treated in Bulletins in course of perparation, dealing with these areas.

The epidote also occurs in veinlets. Some minute opaque gray granular aggregates perhaps represent epidotised felspar laths. There are a few comparatively large yellow chloritic patches that may represent phenocrysts of the original ferro-magnesian.

The structure of the rock is rather similar to that in fine-grained basalts, and from this fact and from the composition of the rock, it is referred to a fine-grained andesitic basalt.

[$\frac{1}{902}$] and [$\frac{1}{898}$] are also fine-grained compact yellowish clayey rocks, but both contain a considerable number of small weathered circular patches or spheroids. Owing to their extremely weathered nature, the rocks are very difficult to section, but slides prepared by special treatment of the rock with balsam show a fine-grained loose plexus of felspar laths with granular chloritic material probably derived from augite. There are also obscure circular forms containing quartz and chlorite, which are referred to vesicles, and occasional rather large, fine scaly chlorite patches that may have been phenocrysts of augite.

Both in outward appearance and in microscopic characters these two rocks very clearly resemble [$\frac{1}{359}$].

It is noteworthy that **93d** [$\frac{1}{903}$] from No. 2 shaft (east of the Ingliston Extended East, see above) end of East crosscut, is rather different from the other rocks from this shaft. It is composed of a greenish and yellowish-green mass of ragged plates of minute chlorite and talc scales, many of the plates being fibrous. There is, however, no definite structure in the rock, and, owing to the obscurity of its association with the rocks described above, and the indefiniteness of its characters—the result of extreme weathering—its relation to them cannot be established.

(d) It will be remembered that, associated with [$\frac{1}{898}$], are two rocks—**17d** [$\frac{1}{882}$] and **15d**—already described as epidotised quartz dolerites. This close association rather suggests a connection between them and the volcanic series, but no field relations can be made out from the outcrop and the only evidence obtainable points to [$\frac{1}{882}$] and **15d** being intrusive dykes.

III.—Sedimentary Rocks.

The occurrence of these rocks in the Meekatharra area has already been mentioned in a previous chapter. In the course of field work at different times in the past, both Mr. A. Gibb Maitland and Mr. H. W. B. Talbot have noted the presence of sedimentary rocks, and as the results of their observations have not yet been published they have supplied information contained in their notebooks and supplement the evidence from the Meekatharra field collected by the writers of the present Bulletin.

Sedimentary or clastic rocks attain but a very small development in the field. North of the District as defined in Chapter I.,

page 72, eight miles east and south-east of the Ruby Well Leases at the "Harder to Find" Gold Mine Lease, there occurs a series of conglomerates, and south of it, slates, either vertical or dipping at an angle of 60 deg. or 65 deg. These are considered the same series as the Mosquito Creek beds, a group which reaches a great development in the Pilbara Goldfield, where, according to Mr. Maitland,[1] they are overlain unconformably by sandstones and conglomerates of the Nullagine series. Again, a remarkable development of clastic rocks has been revealed from the specimens collected by Mr. Maitland at Mt. Yagahong (figs. 1, 14, 26, and 27); also, according to Mr. Clarke, at Table Top Hill (figs. 15 and 28), fifteen miles further north; and again near the Ruby Well Leases. Neither the Table Top Hill rocks nor those from the Ruby Well Leases, both of which are more shaly and more weathered than those from Yagahong, have yet been microscopically examined.

The Yagahong rocks form a series of three members, of which the upper member is a fine-grained greyish gritty rock with numerous small reflecting surfaces of felspar and quartz crystals; the middle a dense-black, rather hard and very fine-grained indistinctly laminated shaly rock, and the basal member is a coarse granitic conglomerate.

The Greyish Grit:—

In the gritty member, so far as the specimens collected show, there are two varieties, a fine-grained one with a faint yellowish-green tinge, and a slightly coarser one somewhat darker in colour and without the yellowish tinge. The former, represented by [13636], consists of numerous small, squarish, triangular, lenticular and round fragments of clear quartz and clouded kaolinised as well as fairly fresh felspar forming a mosaic pavement with numerous small grains of yellow epidote, and of flakes of greenish chlorite between the felspar and quartz fragments, while here and there are small fragments of yellowish-green hornblende sometimes with a fibrous fringe. The felspars are sometimes untwinned, sometimes twinned on the albite and pericline law, while some show the grating structure of microcline. Some are at least as basic as andesine. At first sight, from the undoubted fragmental structure of the rock, one is inclined to regard it as a epidotic chloritic quartz-felspar arkose. Closer examination, however, reveals some interesting features. In places in the slides are small round or angular patches which are not crystal but rock fragments. Some of these show quite a "flow" structure in thin laths of felspar, others are resolved into a minute microcrystalline mosaic of chloritic scales and felspar or quartz grains, others composed of a dense fibrous felt of minute hornblende needles with a few thin opaque grey granular aggregates

1. Bulletin G.S.W.A., No. 40, p.

that are probably zoisitised or epidotised felspar; still others consist of a plexus of minute felspar laths shot through with minute needles of nearly colourless hornblende and with some granular zoisite; and some of a grey colour or pinkish or reddish tint that resemble in their almost isotropic but faintly crystalline character fragments of some volcanic glasses. From the microscopic character of these fragments there is no doubt that they are of a volcanic nature and related to fine-grained andesites.

The latter variety [13638] consists almost wholly of a mixture of rounded and angular quartz and felspar plates with scattered scales of greenish chlorite and some small aggregates of granular calcite. The felspars are similar to those in the former variety, small plates with the gridiron structure of microcline fully or partially developed being by no means uncommon. The appearance of the rock is very suggestive of a quartz-felspar arkose. Search, however, again reveals the presence of irregularly bounded areas of microcrystallic mosaic of chlorite scales and quartzose plates and of a plexus of minute felspar laths obscured by the development of minute opaque gray granular aggregates. In some cases, the quartz and felspar fragments seem to be enclosed in minute chloritic mosaic. Yellowish epidote and hornblende forms are, however, almost if not wholly absent, though small greenish chlorite scales are scattered over the slide. The structure of the rock is very similar to that of the former variety, a fine-grained mosaic pavement with the crystal fragments in all sorts of angular and lenticular shapes.

It is clear that this gritty member presents unusual features. On the one hand some specimens are fragmental epidotic chloritic agglomerates, on the other quartz-felspar rocks with the structure of arkoses but with enclosed fragments of an igneous rock. Moreover, the enclosed volcanic fragments in most cases closely resemble the fragments already noted in such tufaceous rocks as $\left[\frac{1}{203}\right]$. For these reasons, it would appear that the origin of the rock may be ascribed to volcanic fragments falling amongst the constituents of granitic arkose that was in course of formation. The resemblance between the fragments of the grit and those of $\left[\frac{1}{203}\right]$ point to a contemporaneity in the formation of the rock with the tuffs of the Volcanic Series.

It is interesting to note that recently rocks very similar to these have been discovered by Mr. Jutson near Yilgangi in the neighbourhood of Lake Raeside. These contain fragments in many cases almost identical with those in [13636], and, strangely enough, the rock itself forms the matrix of a conglomerate.

The Black Shale:—

This in sections consists of alternate bands of very fine and coarse opaque granular material. In the fine bands, with high

powers, there are to be seen small scales of green isotropic chlorite, minute grains and rods of rutile, grains of epidote and zoisite, small specks of clear quartz and felspar, and many minute black grains forming a dust probably in part an iron ore, and in part carbonaceous material.

In the coarser bands, the same minerals obtain, but they are larger in size. There are rounded and angular crystals or fragments of quartz and felspar, many scales and flakes of green chlorite, some fine granular calcite and epidote, and the black dust as in the finer bands. The banding is, therefore, due to an ill-defined alternation between fine-grained material and coarser and more quartzose and felspathic varieties of similar mineral constitution, or, in other words, of indurated silt and more gritty bands.

The Conglomerate:—

This consists of pebbles varying in size from an inch to two or three inches in diameter. So far as investigations have gone, the pebbles are mostly of a granite, yellowish or pinkish in colour and composed of felspar, quartz and muscovite. The conglomerate appears to rest directly on an underlying granite.

This succession at Yagahong is a very interesting one and of considerable physiographical value. The sequence of events that have apparently given rise to it are first, a period of fluviatile erosion during which conglomerates were laid down, then a period of depression or subsidence—whether local or not is not known—which allowed the black slaty beds to be formed. Then there took place either a deposition of subaqueous agglomerates or there was a comparatively sudden elevation followed by a period of sub-aerial erosion which caused the formation of the gritty rocks. Apparently this elevation has continued to the present day, though enormous dissection of the strata has taken place since their formation.

Finally, close to the south-eastern edge of the Meekatharra granite in the Haveluck Group and its neighbourhood, there are frequent outcrops of fine-grained gritty sediments, and, in the Haveluck North, of a conglomerate with pebbles similar to those at Yagahong, a pink granite or granitic porphyry with thin quartz veinlets and a yellowish muscovite granite of rather fine grain.

In the Quarry Reserve, which has provided material for building purposes, there is a considerable outcrop of a white extremely kaolinised gritty quartz-felspar rock, of which, however, the origin, owing to extreme decomposition, cannot definitely be made out. The presence in it of occasional fine-grained white silty patches and the similarity in grain and composition to specimens such as [**11213**] and [**11200**] point to its being of arkose origin.

In none of the members of this group is stratification to be seen, but in Shaft 21 of the Haveluck Group there is, according to

Mr. Clarke, an apparent dip south amounting to 58 deg., and in the same neighbourhood similar dips are recorded by Mr. A. Gibb Maitland.

The gritty sediments, which are illustrated by [**11200**], from a point 15 chains east-south-east of Reserve No. 11199, collected by Mr. Maitland, and by $\left[\frac{1}{125}\right]$ from the Haveluck North Lease, collected by Mr. Clarke, are brownish or yellowish fine-grained felspathic grits or gritty sandstones. In section, they consist of a fine-grained mosaic or pavement of irregularly bounded quartz and felspar grains of even size, the felspars, owing to decomposition to kaolin and staining by iron oxide, standing out very distinctly in the slide. Cementing material is poorly developed, but what there is, is in part kaolinic, in part yellow-brown oxide of iron. Secondary deposition of silica appears not to have taken place. A few scales of muscovite occur. Uneven extinction and secondary lamellation as well as bent lamellæ are noticeable at times in the quartz and felspar respectively, though these results were probably produced in the minerals before they were consolidated to gritty sandstones. In [**11213**] and $\left[\frac{1}{125}\right]$ there is a coarser grain than in [**11200**], and

Fig. 88.

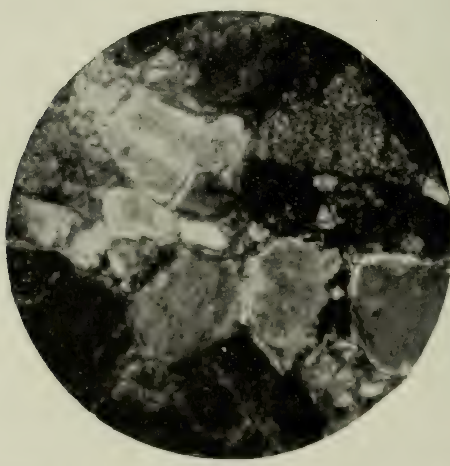


Photo: R. A. F. Neg. 1231.

Microphotograph $\left[\frac{1}{125}\right]$.—The clastic character of the rock is shown by the ragged rounded quartz and felspar crystals separated by a cement.

there appears a greater amount of a kaolinic and siliceous cement, while clastic character is more clearly shown (Fig. 88). The felspars include orthoclase, microcline, and an acid plagioclase.

Owing to the absence of extensive workings on the Haveluck North G.M.L., it was not possible to observe the relation between the granitic pebbles and the gritty sandstones.

No definite relation has, up to the present, been established between these rocks and the quartz-felspar gritty rocks at Yagahong.

4.—SUMMARY AND CONCLUSIONS.

Briefly, the rocks of the Meekatharra Area consist of:—

Granites.—Of these, two varieties have been identified, one, of a grey-green colour, in which the felspars are frequently epidotised, and in which green chloritic biotite and, occasionally, green hornblende occurs; and the other, of a prevailing yellowish tinge, in which muscovite and brown biotite occur to the exclusion of hornblende, and epidote is entirely absent. While the former are probably more accurately described as quartz-diorites than as hornblende granites, the latter show many resemblances to the granite of Southern Cross. Intermediate specimens have been found suggesting a relationship between the two varieties, but no evidence other than the microscopic is available on the point.

Porphyries.—These show a considerable amount of variation both in composition and structure. The majority of the dykes are undoubtedly albite porphyries—closely akin to the quartz-keratophyres from other parts of Australia—of which some contain quartz both as phenocrysts and as a constituent of the ground mass; others are apparently devoid of this mineral, and others again, *e.g.*, the Paddy's Flat dyke, in different parts of the same rock-mass at one time contain quartz as phenocrysts, and at another show no quartz at all.

Less prominent in the area are dykes of peculiar mineralogical character, which have been called chloritic albite porphyries. The relationship between these and the normal albite porphyries is by no means clear, and, though in some cases there is reason for regarding them as unusual varieties of the normal type, consideration of such specimens as [$\frac{1}{321}$] arouses the suspicion that they are extremely albitised forms of a ferro-magnesian rock of dioritic affinities. There is a small development of rocks which have been referred to as granite porphyries, but which exhibit a raggedness of outline in the crystals and a paucity of ground-mass that resemble the characters of some arkoses.

Rocks of Doleritic and Gabbroid Origin.—These include distinct dolerite dykes such as the Ingliston Extended dyke; fine-grained dolerites such as that of the Meeka Hills, which is probably, but not certainly, an intrusive dyke; a large number of comparatively fresh, though, to a greater or less extent, dynamically altered rocks such as uralitised and zoisitised quartz-dolerite or gabbros,

actinolitic-zoisitic amphibolites, fine-grained zoisite-amphibolites, fibrous amphibolites and sheared epidiorites; some chloritised and epidotised quartz dolerites; hornblende schists or sheared amphibolites and foliated black amphibolites. If we exclude the Ingliston Extended dolerite, which is undoubtedly relatively recent in origin, certain similarities in mineral composition and structure, and the occurrence of manifest intermediate varieties indicate a genetic connection between these rocks, which though, in some cases, *e.g.*, the hornblende schists or foliated black amphibolites, rather vague, is in most cases very close.

They also include much altered facies such as the flecked schist, and possibly the chloritic slates and Kyarra schists.

Rocks of Peridotitic Origin.—These comprise fresh serpentines —derived from rocks varying in structure and composition from almost a pyroxenite to a dunite, and much chemically and dynamically altered rocks, some with very indefinite, others with definite traces of former structure, such as talc-chlorite-carbonate rocks, black schists and possibly the fuchsite-quartz-carbonate rocks at least in part.

Rocks of Volcanic Origin.—So far as exposures allow of their identification, there is but a comparatively small development of these rocks in the area. They consist of basic tuffs or agglomerates, crystal-tuffs, augite-andesitic or basaltic rocks with flow structure, and fine-grained weathered basaltic rocks. The mutual relations of the various members of the series cannot be determined owing to the rarity of outcrops. It is probable, however, that later investigations will show that the rocks extend considerably to the east of the area.

Rocks of Sedimentary Origin.—These are found in a few localities, but apparently nowhere reach a large development. They are mostly arkoses or felspathic sandstones and conglomerates, though at Mt. Yagahong, about 18 miles east of Meekatharra townsite, a series has been found, consisting from the base upwards of conglomerates on granite, indurated black slate, and a member best described as a tufaceous arkose, which, in addition to angular quartz and felspar fragments, contain also fragments of an igneous rock of andesitic character. This series presupposes a geological period during which conglomerates were laid down, followed by a period of sudden depression during which the slaty bed was deposited, and then a sudden elevation. During the period after the sudden elevation, arkoses were produced by atmospheric weathering, and, apparently, during their formation, there was an eruption attended with the dispersal of fragments of volcanic rocks.

The chronological sequence of the rock formations cannot be determined with any degree of accuracy. Apparently, however, the oldest rocks are those of doleritic and peridotitic origin. These were, after solidification, strongly affected by dynamic strain producing shearing, saussuritisation of the felspar and uralitisation of the

augite, and were intruded by granite. Contemporaneous with, or subsequent to, the intrusion of the granite, the porphyries made their appearance, and it would appear that the introduction of the gold was due to the residual acid magma of these intrusions. Then followed an eruption of basic volcanic and agglomeratic rocks from vents which have not yet been discovered, but which, judging by the presence of volcanic greenstone ash at Mt. Singleton, cannot have been very far distant. There is no doubt that this eruption was later than the formation of the fibrous amphibolites and the fresh dolerites, for fragments of these rocks have been found in the agglomerates. About the time of this eruption, the arkoses of the neighbourhood were in course of formation. Finally, there was an intrusion of a dolerite dyke represented by the Ingliston Extended dolerite. Outside the area, the gabbroid rock from Barloweerie Peaks, by comparison at any rate with similar rocks from Norseman, is also of comparatively late origin, but there is at present no evidence of its relation in time to the dolerite.

Albitisation in the Area.—Only traces of this have been discovered. The presence of albite due to the alteration of original felspar is noticeable in the uralitised dolerites, the actinolitic-zoisitic rocks, and the fibrous and zoisitic-amphibolites. Again, the presence of veins of albite and quartz indicates a certain amount of albitisation in the fuchsite-quartz-carbonate rocks, though, curiously enough, analyses of the typical emerald-green carbonate fail to show more than a very small percentage of soda in the rock-mass apart from the veins. Finally, the occurrence of such rocks as $[\,\overline{3}\,\frac{1}{2}\,\overline{1}\,]$, as already remarked, points to the possibility of the rocks known as chloritic albite porphyries being but albitised forms of an original type of dioritic affinities.

Petrographical Resemblance between Meekatharra and Kalgoorlie.—Some striking similarities exist in the rocks from the Meekatharra Area and from the North End, Kalgoorlie. In both Areas the gold is found is fairly close proximity to dykes of albite porphyry. In both areas there is a development of uralitised and saussuritised quartz-dolerites, and in both cases this development is in close association with actinolitic-zoisitic rocks and fine-grained amphibolites. At Meekatharra there is a development both of fresh serpentines and talc-chlorite-carbonate rocks derived from peridotites, while at Kalgoorlie, there are similar serpentines at Hannan's Lake, and talc-chlorite-carbonate rocks, *e.g.*, from the Kapai Mine, very similar in appearance to those at Meekatharra, and probably derived from a peridotite. At Meekatharra, the fine-grained actinolitic-zoisitic rocks flank the uralitised dolerites near the old Battery Group, and at Kalgoorlie, identically the same rocks occur near the corner of Hare and Hinemoa Streets contiguous to, and probably passing into uralitised dolerites. Fuchsite-quartz-carbonate rocks occur with the same characters in both areas.

CHAPTER VIII.

THE MINERALS OF THE MEEKATHARRA DISTRICT.

By E. S. Simpson.

In the preparation of the following brief notes upon the various minerals to be found in the Meekatharra District, I am deeply indebted to Mr. E. de C. Clarke for most of the specimens described, and for much valuable information as to their mode of occurrence. Free use has been made of the reports on the district previously published by the State Mining Engineer, Mr. A. Montgomery, and by various officers of the Geological Survey Department.

The subject is discussed under two main headings. Firstly, the individual mineral species are considered in detail from the standpoints of their occurrence, paragenesis, and physical and chemical properties. Secondly, the mineral and chemical composition of the auriferous concentrates produced by several of the gold mines is described.

DETAILED DESCRIPTION OF THE MINERALS.

Native Elements.

Only two of these have been detected in the specimens collected at Meekatharra, viz., graphite and gold. In view of the frequent association of peridotite rocks and arsenical minerals with platinum, this metal was looked for in the concentrates from two gold mines but no trace could be detected.

Graphite (free carbon).—This occurs in small quantities in a few rocks. A massive serpentine [**1 /137**] from the 425ft. level, Ingliston Extended G.M. contains 0·06 per cent. of finely divided graphite. Traces are also present in a chlorite-talc schist [**1 /136**] from the same mine and in a greenstone tuff [**11205**] from 12 chains east of the Marvel Loch Lease.

Gold (native gold alloyed with silver).—The occurrence of gold at Meekatharra is so fully dealt with by Mr. Clarke in his description of the mines that only brief reference to it need be made here. Gold appears to have been profitably worked in several different matrices, viz. :—

- (a) Veins of vitreous quartz, seen in practically every mine.
- (b) Impregnated shear and fracture zones in altered peridotites, e.g., at Fenian and Ingliston Consols Extended Mines.
- (c) Similar zones in altered dolerite, e.g., at Batavia Mine and probably several of the mines at Paddy's Flat.
- (d) Similar zones in ceratophyre, e.g., at Haveluck Mine.
- (e) Similar zones in jasper, e.g., at Queen of the Hill Mine.
- (f) Masses of completely kaolinised rock containing secondary gold and flanking the true outcrops of the deep-seated lodes, e.g., at Gibraltar and Ingliston Extended Mines.

Some wonderfully rich specimens of gold in quartz have been obtained from Meekatharra and Yaloginda, particularly from the Revenue Mine, specimens from which mine and from the Multum in Parvo and Ingliston Consols Extended were exhibited at the Franco-British Exhibition in 1908. The gold in the specimen from the first named mine was found to be 861·2 fine, and that from the last-named, 959·7 fine, the balance in each case being silver. These are the only available assays of native gold from this district. Much of the gold in the rich Revenue specimens was distinctly crystalline, the principal forms developed being apparently the rhombic dodecahedron, octahedron, and cube.

The principal secondary minerals associated with the gold are quartz, arsenopyrite, and pyrite, as well as the various carbonates and hydrous silicates of the shear zones in the altered igneous rocks.

Metallic Sulphides and Sulpho-Salts.

There are remarkably few metallic minerals of this description at Meekatharra. Pyrite and arsenopyrite are the only two which are at all abundant, marcasite is very rare, as also the copper compounds—covellite, chalcopyrite, and tennantite. No trace was observed of any compounds of lead or zinc, both common accompaniments of gold in the Eastern Goldfields; nor of those of bismuth, antimony, and tellurium, which are not infrequently met with in gold ores in other parts of the State.

Covellite (sulphide of copper).—A single small mass was noted in a specimen of milk-white quartz [**1**/**432**] from near the Two Sisters quartz outcrop at Yaloginda.

Chalcopyrite (sulphide of copper and iron).—Several small grains are to be seen in the specimen of quartz from Yaloginda, which carries the covellite mentioned.

Pyrite (sulphide of iron).—This is one of the commonest sulphides at Meekatharra, but is less abundant than arsenopyrite. Occasional grains and crystals are observed in non-auriferous rocks and in quartz veins, but they are common only in the sheared rocks within the auriferous sections, or closely adjacent thereto. Except in some of the jaspery ore in the Queen of the Hill Mine pyrite is never anything but a subordinate constituent of the whole ore. In the majority of cases in the shear zones the mineral is fine grained and well crystallised, the form being almost invariably the pentagonal dodecahedron, with sometimes small bevelling faces of the cube and octahedron. Far less common is the striated cube, which, however, is seen freely in association with uncrystallised pyrite in the auriferous jasper from the deeper levels of the Queen of the Hill Mine. In a specimen of ore from the No. 5 level of the Ingliston Consols Extended, roughly spherical masses of pyrite up to almost an inch in diameter, composed of large interpenetrating dodecahedra, are seen with much free gold embedded in a dark greenstone schist. Surrounding each pyrite mass is a thin border of pale coloured non-ferruginous talc, and scattered freely through the ore are small grains and crystals of pyrite and arsenopyrite. The pyrite in all such ore is plainly the result of the action of sulphur-bearing solutions or vapours upon ferruginous rock-forming silicates such as chlorite or talc, the re-action being somewhat as follows:—

$$\underset{\text{Ferruginous talc}}{6H_2Mg_2FeSi_4O_{12}} + 15S \text{ yield } \underset{\text{Non-ferruginous talc}}{4H_2Mg_3Si_4O_{12}} + \underset{\text{Pyrite.}}{6FeS_2} + 8SiO_2 + 2H_2O + 3SO_2.$$

This reaction explains the association of secondary non-ferruginous talc with pyrite in the Ingliston Consols Extended ore.

Marcasite (sulphide of iron).—A single specimen, in which this mineral is associated with quartz, was collected by Mr. Clarke at the Sirdar Group.

Arsenopyrite (sulpharsenide of iron).—The specimens of ore and concentrates in the Departmental collection indicate that this is the most important metallic mineral in the lodes at Paddy's Flat. The proportions present in four concentrates were :—

Ingliston Extended G.M.	25·3 per cent.
Ingliston Consols Extended G.M. ..	62·4 per cent.
Marmont G.M.	64·7 per cent.
Fenian G.M.	66·4 per cent.

In each case the mineral was found to contain a little nickel, amounting in the second case to about 0·5 per cent.

Like pyrite, this mineral is seldom seen in the quartz veins but is common in the metasomatic rock of the lode formations. In all instances it is in small well-formed crystals scattered through the ore. The crystal form is mainly a combination of the unit prism (110) with the unit macrodome (101).

A fine-grained ceratophyre, [**1** /**90**], from the No. 5 Level of the Fenian G.M. was found to carry 0·85 per cent of this mineral.

The source of the mineral in every instance appears to be the inter-action between ferruginous silicates, such as chlorite or talc, and magmatic emanations carrying sulphur and arsenic. This would account for its common occurrence in the metasomatic auriferous rocks and its almost complete absence from the auriferous quartz veins.

Tennantite (sulpharsenite of copper).—A few small specks of this mineral were observed in concentrates from the Ingliston Consols Extended G.M.

Halogen Compounds.

Salt (chloride of sodium).—This was the only halogen compound observed amongst the Meekatharra specimens. It is abundantly dissolved in the underground waters, forming usually about 50 per cent. of the total solid matter, and appears in isotropic fibres associated with granular epsomite in an efflorescence collected by Mr. Clarke in some underground workings on the Black Jack Group at Yaloginda.

Oxides and Hydrated Oxides.

Quartz (oxide of silicon).—Vitreous quartz is an important constituent of the granites and acid porphyries and, in addition, veins of it are abundant throughout the district, many of them being payably auriferous, others, again, almost or quite devoid of gold.

The vein quartz varies in colour at the surface from milk white, for example [**1** /**432**], Sisters vein, to dark brown, [**1** /**397**], Kyarra Reef ; and, where unoxidised, from milk-white, [**1** /**420**], Marmont, 320ft. level, to light or dark grey, [**1** /**409**], Coronation

Group, and [**1**/**419**], No. 5 level, Ingliston Consols Extended Mine. In structure it varies considerably, from dense vitreous, [**1**/**408**], Hicks' main shaft, through the more common subvitreous of the Paddy's Flat Mines (mostly massive but sometimes vughy), to fine granular, tough [**1**/**429**], or crumbling [**1**/**430**], both from Two Bells Lease at Yaloginda. Under the microscope the most vitreous quartz, such as [**1**/**408**], Hicks' shaft, or [**1**/**397**], 30ft. level, Kyarra Mine, is seen to consist wholly of large interlocked grains, from one to several millimetres in diameter. The common subvitreous varieties, e.g., [**1**/**406**], from the main vein, New Orleans G.M., or [**1**/**419**], No. 5 level, Ingliston Consols Extended G.M., are seen under the microscope to consist largely of coarse-grained quartz, 0·5 to 3·0 millimetres in diameter, with a little interstitial quartz which is much finer grained, 0·02 to 0·05 millimetres, and akin to chalcedony. The granular quartz of the Two Bells Lease, already referred to, is exceptional in structure, being composed almost wholly of grains from 0·04 to 0·20 mm., which are apparently only imperfectly cemented together. It would be impossible in the present imperfect state of our knowledge to decide whether there is any relationship between the structure of the quartz and its richness in gold.

In all cases the vein quartz appears under the microscope to be very full of a greyish "dust," which, under high powers, is seen to be mainly minute pores filled with liquid or gas, or sometimes with both. True mineral inclusions in the quartz are rare and are confined mainly to carbonates, with rarely a little pyrite or iron hydrate pseudomorphs. The evenly brown colour of some weathered quartz, e.g., [**1**/**397**], Kyarra Mine, is due to the filling with iron hydrates of minute secondary cracks between and across the original quartz grains.

Two specimens of quartz collected by Mr. Clarke are exceptional in structure. In one, [**1**/**818**], from the "vughy vein" at the Sabbath Group, the whole structure is botryoidal owing to the growth of the quartz having been in masses of concentric radiating crystals. At the centre of each group of crystals is a small vugh. The quartz from the "sandy leader" on the No. 1 level of the Ingliston Extended Gold Mine is a very loosely coherent mass of small prismatic crystals without orientation, mixed with finely granular quartz.

Chalcedony is a constituent in varying proportions of the jasper bars. [**11197**] from $1\frac{1}{2}$ miles E.S.E. of Clarence G.M.L. is practically pure chalcedony of a grey colour, translucent and flint-like, with indistinct parallel banding and with some narrow bright red streaks coloured by haematite.

Specimens of ore (jasper bar) from the Nos. 3 and 4 level of the Queen of the Hill G.M. consist mainly of chalcedony with a fair amount of pyrites and a little haematite and magnetite.

Cuprite (oxide of copper).—A little cuprite occurs with malachite in the Mount Gibbs Copper Mine at Chunderloo, 11 miles S.W. of Meekatharra.

Haematite (oxide of iron).—This is apparently confined to the jasper bars, of which it is a constant constituent, though in very variable proportions. Some specimens from these masses are almost entirely chalcedony with a few red bands, in which a microscopic dust of haematite is scattered through the preponderating chalcedony, for example, at Luke's Trig., [**11198**], and 1½ miles E.S.E. of Clarence Lease [**11197**]. In other cases the haematite is much more plentiful, for example, in [**11203**] from the Mystery Lease, half-mile west of the Fenian Mine. This contains about equal proportions of cryptocrystalline quartz and haematite, the latter partly as a bright red pigment, partly in coarse grains which are black and glistening. The distribution of the constituents constantly gives a rough banding to the rock. In [**11194**], from near the Clarence Lease, thin bands of almost pure haematite alternate with red or dark brown bands of true jasper. At the Black Jack Mine at Yaloginda some of the haematite bands are in the form of a soft black powder, associated with harder black and red bands. In no part of the district do the jasper bands develop into massess of haematite of sufficient purity and extent to form iron ores.

In all the cases described the jasper appears to be a metasomatic replacement of a ferruginous greenstone schist, which has been subjected to the action of highly carbonated and at the same time oxidising waters. These have attacked the silicates forming iron and aluminium hydroxides and calcium and magnesium carbonates together with free silica, all the products of decomposition being removed in solution except the almost insoluble iron oxide and silica.

Ilmenite (oxide of iron and titanium).—This, in small black grains, is a minor constituent of the least altered dolerites. It was detected in small amounts in the concentrates from the Ingliston Extended and Commodore Mines. In many of the altered rocks it has been converted into rutile, in others into leucoxene.

Magnetite (oxide of iron).—This occurs as a minor constituent of many of the less altered rocks. Thus, on crushing and concentrating 100 grammes of the gneissic granite from a point two miles north of Yaloginda, the concentrates separated by methylene iodide of density 3·3 weighed about 0·14 per cent. of the whole rock and consisted mainly of granules of magnetite, many crystallised in perfect octahedra.

The majority of the specimens collected from the jasper bars are free from magnetite, as shown by their failure to affect a compass, but some specimens from these banded haematite-quartz veins carry sufficient magnetite to have a strong effect upon a compass

needle, e.g., [**11194**], from near the south-west corner of the Clarence Lease. The auriferous jasper in the Queen of the Hill G.M. carries a little granular magnetite at times.

Chromite (oxide of iron and chromium).—In an area containing considerable masses of peridotite one would expect this mineral to be moderately plentiful. In much of the altered variety of this rock, however, the original chromite has been completely altered with the formation of chrome mica, fuchsite, q.v. No hand specimens of chromite have been found, but small grains have been separated and determined with certainty from a massive serpentine rock, [**1/137**], from the Ingliston Extended Mine, and from the auriferous concentrates from the Commodore Mine.

Rutile (oxide of titanium).—This mineral, in microscopic prismatic crystals and grains, is widespread as an alteration product of ilmenite in many metasomatic rocks, e.g., the fuchsite-mesitite rock of the Commodore Mine, the talc-chlorite-ankerite rock of the Fenian Mine, and the highly micaceous schist found in the Queen of the Hill Mine, which carries 2·5 per cent. of rutile. It was also detected in all the concentrates from the Paddy's Flat Mines, derived doubtless from the lode-formations.

Iron Hydrates.—These are abundant as products of weathering of the rock forming silicates, of the ferruginous carbonates of rocks and lodes, and of the pyrite and arsenopyrite of auriferous lodes. Several species are recognised by Dana having different ratios of ferric oxide to water. Of these, Xanthosiderite ($Fe_2O_3.2H_2O$), is readily distinguished by its bright yellow colour, and Turgite ($2Fe_2O_3 \cdot H_2O$) by its decrepitation when heated. Limonite ($2Fe_2O_3 \cdot 3H_2O$), and Goethite ($Fe_2O_3 \cdot H_2O$), (except when the latter is crystallised) can only be definitely determined by analysis.

The bright yellow kaolinised schist from Garden Gully, which on crushing would yield a good yellow ochre, owes its colour to the presence of much xanthosiderite. The same mineral is found in weathered lodestuff as the result of oxidation of mesitite, e.g., in that from the Ingliston Extended and Commodore Mines. In this it appears as a soft, bright yellow powder, through which are scattered small grains of fuchsite and quartz, which proclaim its origin.

Turgite was detected in brown masses with quartz in oxidised ore from the Commodore Mine.

Limonite, the commonest of all iron hydrates, is doubtless plentiful amongst the brown decomposition products of the zone of weathering, which have not been examined in detail.

Psilomelane (hydrated oxide of manganese).—Thin dendritic films of this were observed on the surface of cracks in a much weathered greenstone from the Hornsby Group.

Carbonates.

Carbonates of the alkaline earths are abundant throughout the district, originating as at Kalgoorlie and elsewhere in the State, from the deep-seated action of magmatic carbonic acid on rock-forming silicates. The action on doleritic rocks which contain a fair proportion of lime has been to produce calcite where the amount of carbonic acid was not molecularly in excess over that of the lime. Ferruginous dolomite or ankerite was, however, formed where the supply of acid was more abundant. In the case of peridotitic rocks or related rocks which contain very little lime, only small quantities of calcite with serpentine have formed with very limited supplies of carbonic acid, whilst with greater supplies the action has been more intense, serpentine being first converted into talc and mesitite, and subsequently in places all magnesium and iron silicates have been destroyed with the formation of mesitite and quartz.

Calcite (carbonate of calcium).—Hand specimens of this mineral are not frequently obtained, but microscopic grains are common in the carbonated greenstones. Thus an analysis of [**1/137**], a fine-grained serpentine from the Ingliston Extended Mine, revealed the presence of 6 per cent. of calcite, and, similarly, 6½ per cent. was detected in a tuff [**11205**] from a point east of the Marvel Loch Lease. Small grains were detected in most of the auriferous concentrates, being derived from the auriferous shear zones. It was most abundant in the concentrates from the Commodore Mine, of which it formed almost 13 per cent.

A fault plane at the No. 3 level of the Ingliston Extended G.M. was filled with a thin ($\frac{1}{8}$ to $\frac{1}{4}$ inch) sheet of white and pale-grey fibrous calcite. Fibrous and lamellar serpentine coated both faces of the sheet.

Dolomite (carbonate of calcium and magnesium, usually with some iron).—Dolomite is more abundant at Meekatharra than calcite, and occurs mostly in microscopic grains throughout the carbonated greenstones. Being derived from more or less ferruginous calcium-magnesium silicates by deep-seated carbonation *in situ*, the dolomite is invariably ferruginous and usually sufficiently so to be designated Ankerite ($2CaCO_3.MgCO_3.FeCO_3$).

Two rocks which were analysed contained a notable amount of finely divided ankerite, viz. [**1/200**] and [**1/204**], both chlorite schists from the Commodore Mine, which carried 9 per cent. and 24 per cent. of this mineral respectively. In a third rock of the same nature, [**1/209**], from the No. 3 level in the Fenian Mine, nearly 20 per cent. of ankerite was present in the form of prominent lenses and small scattered rhombohedra, easily detected by the unaided eye.

Mr. H. P. Woodward collected at Meekatharra in 1909 a fine specimen of white to pale-grey coarsely crystalline ankerite [**10721**],

which completely filled a vein four inches wide in carbonated greenstone. A ferruginous dolomite, probably ankerite, is present in the concentrates from most of the Paddy's Flat Mines.

The first stage in the weathering of this mineral is illustrated by [**10719**] from the Marmont Mine. This is a vein filling consisting of about equal amounts of quartz and coarsely crystalline ankerite, the latter of which is dark brown in colour from the conversion of much of the contained ferrous carbonate into ferric hydrate.

A large boulder, with typical septarian structure, [**1/817**], was found by Mr. Clarke in weathered rock in a small shaft 20 chains south of the Sirdar Group. The structure of the outside of the boulder is small pisolitic, inside that dense and compact, with a minute crystalline crust lining the numerous wide septarian cracks which radiate roughly from the centre. That these are shrinkage cracks is very evident from the matching of opposing irregular surfaces. The whole boulder is of a uniform purplish-red colour, due to evenly distributed iron hydrate dust, which can be separated by attacking the mineral with dilute nitric acid. Apart from this pigment the composition is that of a pure dolomite, an unusual composition for a septarian nodule. The only way to account for the gaping shrinkage cracks in the interior of a boulder with unbroken crust is to assume that the mineral was originally precipitated as a hydrated carbonate akin to the Gajite of Plese in Croatia,[1] and that this was subsequently converted into dolomite by dehydration accompanied by a shrinkage in volume of something like 30 per cent. The oxidation of original ferrous carbonate would account for the colour.

Mesitite (carbonate of magnesium and iron).—A ferruginous magnesium carbonate which is abundant at Meekatharra, and which in its composition and chemical behaviour is distinct from true magnesite, must be looked upon as mesitite. It occurs in lodes and barren rocks, mainly if not wholly below water level, and in association either with talc and chlorite or with fuchsite and quartz. Its origin in either case is plainly to be traced to the deep-seated carbonation of ferruginous magnesium silicates such as talc or serpentine, the latter either free serpentine or the serpentine molecule of chlorite. Thus—

$$\underset{\text{Serpentine}}{2\,H_4(Mg, Fe)_3Si_2O_9} + 3\,H_2CO_3 \text{ yield } \underset{\text{Mesitite}}{3(Mg, Fe)\,CO_3} + \underset{\text{Talc.}}{H_2(Mg, Fe)_3Si_4O_{12}} + 6H_2O$$

$$\underset{\text{Talc}}{H_2(Mg, Fe)_3Si_4O_{12}} + 3\,H_2CO_3 \text{ yield } \underset{\text{Mesitite}}{3\,(Mg, Fe)\,CO_3} + \underset{\text{Quartz}}{4SiO_3} + 4H_2O.$$

See also under fuchsite.

[1] See H. Leitmeier, Wasserhaltige dolomitähnliche Mineralien, in Doelter, Handbuch der Mineralchemie, I., pp. 401, 402.

Mesitite has already been described as occurring under precisely similar conditions at Kalgoorlie[1] and Kanowna.[2] References to similar occurrences abroad are rare, but Redlich[3] refers to what appear to be similar conditions in Styria and Tyrol.

The paragenesis of this mineral in Western Australia may be tabulated thus—

Paragenesis of Mesitite.

—	Type A.			Type B.		
	Meekatharra.	Kalgoorlie.	Kanowna.	Meekatharra.	Kalgoorlie.	Kanowna.
Mesitite	X	X	X	X	X	X
Ankerite	x	x	x	X x	x	X x
Talc	x —	x	x	X	X	X x
Chlorite	—	—	x —	x	X	X
Fuchsite	X	X	X	—	—	—
Biotite	—	—	—	—	—	x —
Tourmaline	—	x —	—	—	—	—
Quartz	X	X	X	x	x —	x
Rutile	x	x	x	x	x	x
Pyrite	x	x	x	x	x	—
Arsenopyrite	x —	—	—	x —	—	—
Gold	x —	—	—	x —	—	—

Significance of symbols: X, major constituent; x, minor constituent; —, absent; x —, sometimes a minor constituent, sometimes absent; X x, sometimes a major constituent, sometimes a minor.

This table may be compared with that given by Redlich on page 249 of the first volume of Doelter's Handbuch der Mineralchemie. Redlich's "chromiferous talc" may well be fuchsite, since it has probably been named as the result of microscopic examination, by which alone talc and muscovite cannot easily be differentiated.

At Meekatharra the mesitite in the fuchsite rock is either finely granular and evenly distributed, or is in somewhat coarse aggregations. It is white to pale grey in colour, and sub-translucent to opaque, except in thin section. Chemically it is distinguishable from all other carbonates by its greater resistance to the action of acids. In 5E hydrochloric acid, even in fine powder, it only begins to dissolve at a temperature of about 95° C. and even on boiling, solution is slow.

In the zone of much weathered (kaolinised) rock, mesitite is found to have suffered complete decomposition with the formation of iron hydrates and pure magnesium carbonate, most of the latter being removed by solution in percolating waters.

[1] E. S. Simpson, Mineralogy of Kalgoorlie, G.S.W.A. Bulletin 42, pp. 128, 139.

[2] E. S. Simpson, Carbonate Minerals occurring in certain Kanowna Rocks, G.S.W.A. Bulletin 47, pp. 96, 97.

[3] K. A. Redlich, Entstehung und Vorkommen des Magnesits. In Doelter, Handbuch der Mineralchemie, I., 247.

Magnesite (carbonate of magnesium).—No non-ferruginous magnesium carbonate has been obtained below water level. Above that level, as already stated, ferruginous varieties have been converted into iron hydrates and pure magnesite, most of which has been removed in solution, but some has remained behind close to the surface in the form of concretionary boulders. A specimen [**11211**] from one of these boulders collected by Mr. H. P. Woodward is composed of almost pure white magnesite, very hard and fine grained, with a conchoidal fracture, the mineral resembling a semi-porcelain. It is traversed by one or two minute cracks filled with glassy quartz. On treatment with warm dilute hydrochloric acid the greater part of the mass dissolves with effervescence, leaving behind a very light skeleton of gelatinous silica, derived from the breaking up of associated sepiolite (meerschaum).

Some white nodules, partly hard and dense, partly soft and porous, collected by Mr. Clarke in decomposed peridotite at a depth of 80 feet at the south end of the Ingliston United Lease were found to consist mainly of magnesite, with appreciable amounts of sepiolite, the hard nodules containing the greater proportion of the silicate, together with free silica.

Malachite (hydrous carbonate of copper).—This is very rare in the area embraced by Mr. Clarke's map. Small amounts were detected in concentrates from oxidised ore from the Commodore Mine.

At Chunderloo, eleven miles S.W. of Meekatharra township, a small copper mine, the Mount Gibbs, is now working and has shipped a few tons of high grade ore in which the metal is almost wholly in the form of malachite. The State Mining Engineer informs me that stains of malachite are freely visible in the ore from the upper levels of the Chunderloo Gold Mine at the same centre.

Anhydrous Silicates.

With the exception of albite and zircon these are practically confined to the non-auriferous rock masses, details of which are given in the chapter on the Petrology of the district. Only the briefest reference will therefore be made to them here.

Microcline (silicate of aluminium and potassium).—This is abundant as a primary constituent of the granites and pegmatites of the district. Small amounts of a potash felspar are also found in the porphyry dykes.

Albite (silicate of aluminium and sodium).—Albite forms the major portion of several dykes of ceratophyre. Thus [**1/90**], a dyke rock from the No. 5 level of the Fenian Mine, carries about 55 per cent. of albite; [**11202**], from the 68 mile-peg on the Peak Hill Road, about 80 per cent. albite; and [**1/113**] from the same

neighbourhood, about 85 per cent. of this mineral. [**1/109**], from a shaft near the north end of the Yaloginda Belt, is practically pure albite, as the following analysis of the rock shows :—

——	Albite-rock, Yaloginda.	Pure Albite.
	per cent.	per cent.
Silica	68·19	68·78
Alumina	19·47	19·43
Ferric oxide	·08	..
Ferrous oxide	·24	..
Magnesia	·13	..
Lime	·21	..
Soda	11·60	11·79
Potash	·06	..
Ignition loss	·26	..
	100·24	100·00

Analyst: H. Bowley.

The carbonation of doleritic and peridotitic rocks, which is so common in the district, results in the development of calcite and secondary albite from primary labradorite or a related felspar. The albite thus formed occurs as a minutely granular component of the altered rocks, associated with sericite, chlorite, and other secondary minerals.

Oligoclase (silicate of aluminium, sodium, and calcium).—A felspar, probably of this species, is a granular constituent of the granites and a porphyritic constituent of the porphyry dykes. See, for example, the description of [**11767**] by the Petrologist in Bulletin 43, page 82.

Labradorite (silicate of aluminium, sodium, and calcium).—This is a prominent constituent of the little altered Ingliston Extended dolerite, see [**11758**].

Pyroxene, Augite (silicate of calcium, magnesium, iron, and aluminium).—A major constituent of the previously mentioned dolerite occurring at Paddy's Flat.

Amphibole (silicate of calcium, magnesium iron, and aluminium).—Actinolite and hornblende are abundant near Garden Gully and Yaloginda in uralitised dolerites and hornblende schists, which have been but little or not at all affected by deep seated carbonation.

Garnet (**Almandite ?**) (silicate of iron and aluminium).—By crushing and concentrating 100 grammes of a pegmatite forming a vein in greenstone schists at Chunderloo, about 0·7 gramme of garnet of a pale red colour was obtained. The mineral was all in more or less perfect rhombic dodecahedra, 0·04 to 0·20 millimetres in diameter.

Zircon (silicate of zirconium).—Occasional minute crystals of zircon were observed in the gold-bearing concentrates from the Kyarra, Fenian, and Ingliston Consols Extended Mines, and in the concentrate obtained by crushing, washing, and treating with methylene iodide a granite gneiss from near Yaloginda.

Sphene (titano-silicate of calcium).—This has been recorded in the granites by the Petrologist. The concentrate from 100 grammes of gneissic granite from two miles north of Yaloginda contained many granules of sphene, as also did the auriferous concentrates from the Fenian, Ingliston Extended, and Ingliston Consols Extended Mines.

Hydrous Silicates.

Zoisite (hydrous silicate of aluminium and calcium).—This occurs only as microscopic granules in altered lime-bearing felspars of the granites and metasomatic dolerites.

Epidote (hydrous silicate of aluminium, iron, and calcium).—No hand specimens of this mineral have been recorded, but it has been observed in microscopic grains in altered granite, and more abundantly in metamorphosed doleritic rocks from various parts of the district.

Tourmaline Group (hydrous borosilicates of aluminium, sodium, magnesium, and iron).—The minerals of this group are not characteristic of the ore deposits of Meekatharra, though rarely a microscopic needle has been detected in concentrates from the mines, e.g., those from the Fenian and Ingliston Consols Extended. Nor does tourmaline occur as a metasomatic product in the various altered greenstones of the district. Specimens, however, collected by Mr. Clarke show its presence in auriferous and non-auriferous vein-quartz and in vughs in a ceratophyre dyke.

A specimen illustrating the last-named occurrence is [**7678**], from a depth of 80 feet in the ceratophyre dyke on the Gwalia Extended G.M. at the southern end of the Paddy's Flat Belt. This consists of coarsely crystallised quartz and black tourmaline with masses of finely granular albite. Considerable air spaces are present. The tourmaline is in acicular bundles which interpenetrate in all directions. The colour in mass is brownish black; under polarised light the colours are very pale smoky yellow parallel to the vertical axis, deep Payne's-grey at right angles to it. The total iron in the mineral is equal to 6·73 per cent. of ferrous oxide, whilst the magnesia apparently exceeds this amount. The species is therefore a ferruginous **Kalbite**.

A. Montgomery records[1] in the upper levels of the Gwalia Mine "much white kaolin, and this contains veins of quartz with bunches of black tourmaline in radiating acicular bundles."

[1] Rept. Dept. Mines, W.A., for 1907, p. 112.

Vein quartz, apparently non-auriferous, from an abandoned shaft about midway between Meekatharra and Garden Gully, contains roughly parallel black bands owing their colour to a minutely fibrous belt of black tourmaline.

From a flat cross reef at Jackson's Group, Mr. Clarke collected a specimen of a vein [**1**/**816**] about three inches wide with a sharp line of demarkation down the centre parallel to the walls. One half consists of clean milky quartz in which no gold is visible, the other half of a mixture of quartz and black acicular tourmaline in about equal proportions, with two coarse grains of gold embedded in it. This is the only case observed of gold and tourmaline in association at Meekatharra.

The dichroism in all three cases described was the same, indicating that all belong to the same species, viz., Kalbite.

Muscovite (hydrous silicate of aluminium and potassium).—In the form of secondary sericite this mineral is abundant. It appears to some extent as the result of alteration of potash felspar in the granites and porphyries, but far more abundantly as the result of extreme metasomatism of doleritic rocks, associated with the introduction of external potash both from magmatic water and from circulating underground water which has picked up potash during the weathering of various rock masses. An extreme example of this is a sericite schist [**1**/**198**] from the Queen of the Hill Mine, the analysis of which, given below, shows it to consist almost wholly of muscovite.

Sericite Schist, Meekatharra.

	per cent.
Silica	47·21
Alumina	31·27
Ferric oxide	1·43
Ferrous oxide	·33
Magnesia	1·64
Lime	·14
Soda	·14
Potash	11·12
Water below 100°	·06
Water above 100°	4·37
Titanium oxide	2·56
	100·27
Sp. Gr.	2·86

Analyst: H. Bowley.

A similar, almost pure sericite rock was also collected from a band in sheared amphibolite on the Two Bells Lease at Yaloginda.

Apart from these extreme examples, small quantities of sericite are distributed widely throughout the masses of altered dolerites.

The alteration under similar conditions of the most basic rocks carrying chromite has produced not typical muscovite, bu

the chrome bearing variety, **Fuchsite**. The first record of this unusual and interesting mineral in Western Australia was made by the writer in 1900[1] on material collected at the Kalgoorlie North End. Subsequently it was recognised as abundant at Kanowna, Menzies, Meekatharra, Sherlock Station, and elsewhere. It is invariably found within or adjacent to crushed and highly metasomatised peridotites (possibly at times pyroxenites) whose alteration has been influenced by intrusions of potash-bearing rocks, usually porphyries. It is produced by the deep seated alteration of aluminous silicates (such as the secondary edenite or aluminous actinolite of serpentines or metasomatic pyroxenites, or the chlorite of talc-chlorite rocks) and of the associated granules of chromite by carbonic acid and potash bearing waters at high temperature and pressure. Chromite, under all other conditions so resistant to alteration, is completely decomposed under these conditions. At the same time the serpentine or talc is also attacked. The initial minerals are—

Serpentine, $H_4 (Mg, Fe)_3 Si_2O_9$, or Talc, $H_2(Mg, Fe)_3 Si_4O_{12}$.

Edenite, $(Mg, Fe)_2Al_4Si_2O_{12}$, or other aluminous Amphibole or Chlorite.

Chromite, $FeCr_2O_4$.

The resulting products are—

Mesitite, $(Mg, Fe)CO_3$.
Quartz, SiO_2.
Fuchsite, $H_2K(Al, Cr)_3Si_3O_{12}$.
Talc, $H_2(Mg,Fe)_3Si_4O_{12}$.

This combination of minerals being that commonly found in most of the localities mentioned.

The action has plainly involved the absorption of much external carbonic acid and potash, whose source must be looked for in the later porphyry or granite intrusions. The changes which result in the production of fuchsite are probably those represented in the following equation, the silicic acid in which is derived from associated serpentine undergoing simultaneous alteration by carbonic acid.

$$\underbrace{(Mg, Fe)_2Al_4Si_2O_{12}}_{\text{Edenite}} + \underbrace{FeCr_2O_4}_{\text{Chromite}} + 4\,H_2SiO_3 + 2\,KHCO_3 + H_2CO_3$$

yield

$$\underbrace{3(Mg, Fe)\,CO_3}_{\text{Mesitite}} + \underbrace{2\,H_2K\,(Al, Cr)_3\,Si_3O_{12}}_{\text{Fuchsite}} + 4\,H_2O.$$

The fuchsite of Meekatharra is of a bright emerald green colour, of slightly varying shades. It is at times fairly evenly distributed in microscopic scales throughout the uniformly granular mesitite-quartz rock, as for example in specimens collected from the 200ft. level at the Globe Mine, giving the whole rock an almost uniform rich green colour. Such a rock, if it could be obtained in blocks of

[1] An. Rept. of the G.S.W.A. for 1900, p. 32

suitable size, would constitute a highly ornamental stone of the marble type for internal architectural work.

At other times, as in specimens from the Ingliston Extended mine, the structure is gneissose, the various constituents being in rudely defined bands or thin lenses. The fuchsite is then in foliated masses often comparatively free from other minerals.

A specimen [**1**/**416**] of rich ore from the spur reef below No. 3 level, Ingliston Extended G.M., shows abundant fuchsite in somewhat lenticular masses in a white quartz reef with a considerable proportion of irregularly distributed carbonates. Small crystals of pyrites are somewhat abundant in the fuchsite masses though practically absent from the rest of the ore. No gold is visible. In thin section the fuchsite is faintly pleochroic, emerald green to bluish green, in all other respects it resembles ordinary sericite.

Fuchsite was detected in concentrates from the ore from two mines at Paddy's Flat, viz., Commodore and Ingliston Extended

Biotite (hydrous silicate of potassium, aluminium, magnesium, and iron).—Biotite occurs as a rock-forming mineral only in the granitic rocks. It is not seen in the altered dolerite or peridotite nor in any of the ores. Elsewhere also in Western Australia biotite is absent from the metasomatic gold ores, though at times, as at Ora Banda, present in small amounts in the similar but barren rock immediately adjacent to the auriferous zones.

Chlorite Group (hydrous silicates of aluminium, iron, and magnesium).—Minerals of probably more than one species in this group are amongst the commonest minerals in the district. They are important constituents of the variously altered phases of dolerite and to a less extent in some of the altered peridotite. They are associated with one or more of the following :—ankerite, mesitite, and talc, with less abundant albite, quartz, sericite, and rutile. The deep colour and high percentage of ferrous iron in many examples suggest that the species present in these cases is **Prochlorite.**

Chlorite is a somewhat important constituent of the auriferous shear zones (lode-formations) below water level in most of the mines.

Serpentine (hydrous silicate of magnesium and iron).—Although there are considerable masses of altered peridotite in the district, serpentine is not a common rock constituent, a further alteration to talc having been widespread. A dense unsheared rock from the Ingliston Extended mine which was analysed appears to consist largely of serpentine. Other serpentinous modifications of the peridotite are described by the Petrologist. The mineral was detected in concentrates from the Ingliston Extended, Ingliston Consols Extended, and Fenian Mines.

The filling of a fault plane traversing the east lode at a depth of 425 feet in the Ingliston Extended Mine is unusually interesting. The filling varies from $\frac{1}{8}$ to $\frac{1}{2}$in. in thickness and the centre portion

is composed of dark green foliated serpentine with occasional thin lenses of calcite. On either side of this central portion is a thin ($\frac{1}{16}$ to $\frac{1}{8}$ inch) layer of finely fibrous **Chrysotile** (fibrous serpentine), the fibres lying almost parallel to the walls of the fault owing to dislocation after their first formation, the original direction of the fibres being always at right angles to the face of the fissure. On the outside of the chrysotile again is an extremely thin layer of dark olive-green massive serpentine. The chrysotile is of a somewhat unusual colour, dark olive green and strongly pleochroic. When examined with polarised light under the microscope it is chestnut brown parallel to the elongation of the fibres, pale greenish yellow at right angles thereto, the extinction being straight. The fibres divide easily and are extremely fine and flexible. They are readily decomposed by warm strong hydrochloric acid, leaving a fibrous residue of silicic acid. The total iron present is equal to 8 per cent. of FeO, part of this being in the ferric form. The presence of these iron oxides doubtless explains the unusual colouring.

Talc (hydrous silicate of magnesium and iron).—This is a very common rock forming mineral at Meekatharra, and small quantities were detected in all the auriferous concentrates examined. In these it is derived from the auriferous shear zones. In the altered peridotite the talc is derived ultimately from olivine, serpentine being an intermediate stage. In the altered dolerite the talc is derived from amphibole or pyroxene, the serpentine molecule of chlorite being again the intermediate stage. In both cases water and carbonic acid are necessary agents in the transformation, which is represented thus—

$$\underbrace{2\,H_4(Mg, Fe)_3Si_2O_9}_{\text{Serpentine}} + 3\,H_2CO_3 \text{ yield}$$

$$\underbrace{H_2(Mg, Fe)_3Si_4O_{12}}_{\text{Talc}} + \underbrace{3\,(Mg, Fe)\,CO_3}_{\text{Mesitite[1]}} + 6\,H_2O$$

Talc-mesitite rocks are thus formed, and, when the carbonic acid fails to attack the whole of the chlorite, a talc-chlorite-carbonate rock results. In the presence of lime-bearing silicates this carbonate may be wholly or in part ankerite instead of mesitite. Such rocks are, according to Mr. Clarke, of common occurrence at Meekatharra. Local removal of the carbonate by underground waters leaves behind masses of almost pure talc. A typical specimen of this, of a pale greenish colour and slightly foliated structure, was collected from a depth of about 170 feet in the State Battery Well. A second, more strongly foliated, and varying in colour from pale green to light buff (owing to partial oxidation of the iron) was collected along a small fault plane at 300 feet in the Ingliston Extended Gold Mine.

Sepiolite, Meerschaum (hydrous silicate of magnesium).—This occurs in appreciable quantities scattered through concretionary

[1] Or a less ferruginous magnesite.

nodules of magnesite, q.v., Masses of economic value are yet unknown and very unlikely to be found.

Kaolin and **Halloysite** (hydrous silicates of aluminium).—Kaolin is abundant as the final product of weathering of all types of rocks at Meekatharra, where this action reaches in many places to depths well over 100 feet, in fact it is still marked at 300 feet in the Ingliston Extended Mine, see Fig 18. The Survey Collection contains only a single hand specimen [**6972**] of typical halloysite, white in colour, soft and waxy in texture. Two small fragments from this specimen had specific gravities of 2·07 and 2·06, determined by methylene iodide. It was decomposable by strong hydrochloric acid. If we follow the modern method of referring to the species Halloysite all colloidal aluminium silicates which are hydrogels decomposable by strong hydrochloric acid, and in which the ratio $Al_2O_3 : SiO_2$ is typically 1 : 2, but in which it may vary somewhat through the presence of additional free colloidal alumina or silicic acid, then halloysite must be a very common mineral amongst the local products of rock weathering, and possibly is more plentiful than true kaolin, confining this term to the corresponding crystalline silicate not attacked by strong hydrochloric acid.

Chloropal (hydrous silicate of ferric iron).—Typical specimens of the soft **Pinguite** variety were collected by Mr. Clarke in a stope above the No. 3 level in the Queen of the Hill G.M. The mineral occurs freely with shattered quartz as the filling of a small fissure in the fine grained " flecked schists " (of dolerite origin) seven feet west of the large jasper bar on which the Queen of the Hill workings are situated. This association of chloropal with jasper bars appears to be common in Western Australia, but the genetic connection s not obvious.

The Meekatharra chloropal is amorphous, very soft (H. 1), waxy in texture and of a bright epidote-green colour. After air drying for some months the specific gravity of three small fragments was determined by methylene iodide and found to be 2·28, 2·28, and 2·27. It is readily decomposed by hot strong hydrochloric acid, granular silicic acid separating. A qualitative examination showed the presence of abundant silica, water, and ferric oxide, with some alumina, magnesia, and traces of lime. The alumina amounted to 4·2 per cent. as determined by the phenylhydrazine method. In the closed tube the mineral gives off much water and turns black.

Phosphates, Sulphates, etc.

Apatite (fluo-phosphate of calcium).—This is known only as a minor constituent of the various rock masses. An occasional granule appears in the auriferous concentrates produced at the mines.

Scorodite (hydrous arsenate of iron).—Traces of an arsenate were detected in the brown iron ore of the upper levels of the Kyarra Mine. The arsenic is probably present as scorodite which is the commonest and most stable arsenate of iron occurring in surface ores in Australia.

Natronitrite (nitrate of sodium).—This is comparatively abundant in the underground waters into which it finds its way from the surface soil, where the mineral accumulates in the drier seasons.

Gypsum (hydrous sulphate of calcium).—Only one specimen of this mineral was collected, viz., from the Old Battery Group near Garden Gully, but it is of fairly frequent occurrence in the northern part of the area. In the Battery Group specimen it is in clear colourless masses, with columnar structure, scattered through completely kaolinised chlorite rock.

Epsomite (hydrous sulphate of magnesium).—Large quantities of epsomite are dissolved in the underground waters. An efflorescence, partly fibrous, partly granular, from the walls of a drive in the workings on the Black Jack Group, was found to consist of about two parts of fibrous salt (NaCl) with one part of granular epsomite. A second efflorescence from walls of weathered porphyry at 30 feet depth in the Ingliston North G.M. was found to be practically pure epsomite. It was quite white in colour and fibrous in structure.

Natrojarosite (hydrous sulphate of iron and sodium).—A bright yellow ochre occurring in quartz at the No. 2 level, Commodore G.M., yielded an acid water on heating in a close tube, and was proved to contain small quantities of sulphuric oxide insoluble in water. This is probably present as natrojarosite.

Addendum to Minerals.

Pseudobitumen (mainly a mixture of nitrogenous organic compounds).—An account of the minerals of Meekatharra would not be complete without some reference to this substance (often called "dung-bitumen"), a deposit of which was found by Mr. Talbot in a small cave in a granite breakaway a short distance west of the Garden Gully Road, 3¾ miles north of Meekatharra. This substance is frequently mistaken for an oxidation product of mineral oil, being not unlike asphaltum in outward appearance. It is, however, immediately distinguishable from asphalt by its distinctive aromatic smell and by the fact that it is almost completely soluble in water, whilst asphaltum is quite unaffected by water. The solution in water contains principally organic nitrogen compounds, together with compounds of ammonia and potash, and sometimes a little salt. The insoluble matter is sand and dust, with ofttimes small twigs, a little hair, fragments of bone, the

elytra of beetles, and other animal debris. A study of this substance from various localities in the State leaves no doubt as to its nature and origin. Rain water percolating through accumulations of marsupial or bat guano, usually in cave shelters, dissolves out soluble organic compounds and inorganic salts, and the solution on drying, where it has collected in little hollows, or as it trickles down the walls of lower caverns, deposits its dissolved and suspended matter in the form of a black or dark brown, compact, asphalt-like mass.

THE COMPOSITION OF THE AURIFEROUS. CONCENTRATES.

Several samples of concentrates from gold ores were collected by Mr. Clarke and examined in the Laboratory with a view to throwing light upon the mineral associates of the gold in the Meekatharra area, and to assisting the mine managers in developing satisfactory methods of metallurgical treatment. The concentrates were obtained from the Kyarra, Commodore, Marmont, Fenian, Ingliston Extended and Ingliston Consols Extended Mines. With the exception of those from the Kyarra, Commodore and Marmont the samples were obtained from existing concentrating plants, and were sufficiently large for extensive investigation. Those from the Kyarra Mine were on the other hand very small samples obtained by hand concentration by Mr. Clarke himself, and too small for any detailed work to be done on them.

Three methods of examination were utilised :—

(1) Direct chemical determination of important elements and radicles.

(2) Separation with heavy solutions, viz., methylene iodide of several strengths from a density of 2·7 to 3·3.

(3) Microscopic examination.

These were supplemented by examination of typical specimens of the ores from which the concentrates were derived.

Ingliston Extended G.M. Concentrates.—These appear to have been derived almost wholly from sulphide ore. Having been exposed to the air in a damp condition some of the sulphides had partly oxidised and rusted the whole mass. Under these conditions a complete microscopic examination was difficult. The following minerals were however plainly detected :—

Pyrite, arsenopyrite, one or more rhombohedral carbonates, fuchsite, limonite, quartz, black iron ores (ilmenite, etc.), talc, sphene, native gold.

A partial analysis was made with the following results :—

Gold	3 ozs. 6 dwts. 10 grs. per ton.
Silver	8 dwts. 17 grs. ,,
Sulphur	13·84 per cent.
Arsenic	11·59 ,,
Silica	15·70 ,,
Lime	2·48 ,,
Magnesia	10·60 ,,
Acid soluble Iron, Fe	23·85 ,,
Carbonic acid	8·70 ,,
Soluble Alumina and Titania ..	3·57 ,,

From these figures and from separations made with methylene iodide of several specific gravities, the mineral composition was deduced to be—

Minerals with Specific Gravity 3·0 and over	Arsenopyrite	25·3 per cent.
	Pyrite	16·7 ,,
	Magnetite	·9 ,,
	Limonite and Rust ..	2·9 ,,
	Ilmenite with a little Sphene and Rutile	3·0 ,,
	Native Gold	present
	Mesitite	14·6 ,,
Minerals with Specific Gravity under 3·0	Calcite	4·4 ,,
	Serpentine and Chlorite ..	10·6 ,,
	Talc	9·1 ,,
	Sericite and Fuchsite ..	8·4 ,,
	Quartz	4·1 ,,
		100·0

Analyst : E. S. Simpson.

It is probable that part of the calcite and mesitite are com, bined together to form ankerite. No blende, galena, chalcopyrite-tennantite, stibnite, or bismuthinite were observed.

Fenian G.M. Concentrates.—These appear to have been derived mainly from sulphide ore.

Recognisable under the microscope were—arsenopyrite, pyrite, carbonates, talc, quartz, sphene, rutile, tourmaline, and zircon.

The following results of direct estimations are recorded :—

Gold	2ozs. 3 dwts. 13grs. per ton
Silver	6 dwts 13grs. ,,
Platinum	*Nil*
Sulphur	21·37 per cent.
Arsenic	30·60 ,,
Iron, Fe	29·87 ,,
Iron oxide, FeO	2·36 ,,
Silica	4·84 ,,
Lime	1·11 ,,
Magnesia	3·67 ,,
Alumina	2·54 ,,
Titania	·23 ,,
Carbonic acid	3·42 ,,
Nickel	trace
	100·01

No other heavy metal was detected.

The approximate mineral composition of the concentrates is—

Minerals with Specific Gravity 3·0 and over	Arsenopyrite	66·4	per cent.
	Pyrite	15·3	,,
	Limonite	1·2	,,
	Sphene	·4	,,
	Rutile, Tourmaline and Zircon	·1	,,
	Native Gold	present	
	Mesitite	5·6	,,
Minerals with Specific Gravity under 3·0	Calcite	1·8	,,
	Serpentine and Chlorite ..	5·3	,,
	Talc	1·9	,,
	Sericite	·5	,,
	Quartz	1·5	,,
		100·0	,,

Analyst: H. Bowley.

Marmont G.M. Concentrates.—These were derived from sulphide ore.

Under the microscope were seen—

Arsenopyrite, largely in crystals which were a combination of the unit prism (110) with the unit macrodome (101).

Pyrite, mostly crystallised in pentagonal dodecahedra, rarely in cubes.

Quartz, carbonates, talc, sericite, limonite, native gold, and a granular mineral like rutile.

The analytical figures obtained were—

Gold	2 ozs	8 dwts. 14 grs. per ton.
Silver		5 dwts. 20 grs. ,,
Sulphur	27·51	per cent.
Arsenic	29·77	,,
Silica	3·12	,,
Lime	*Nil*	
Magnesia	·47	,,
Acid-soluble Iron	35·96	,,
Carbonic acid	1·28	,,

No compounds of zinc, lead, copper, antimony, or bismuth could be detected.

The approximate mineral composition calculated from the results obtained was—

Specific Gravity 3·0 and over	Arsenopyrite	64·7	per cent.
	Pyrite	27·5	,,
	Limonite and Rutile ..	·5	,,
	Mesitite and Siderite ..	2·8	,,
Specific Gravity under 3·0	Chlorite and Serpentine ..	·5	,,
	Talc	1·0	,,
	Sericite	1·0	,,
	Quartz	2·0	,,
		100·0	

Analyst: H. P. Webb.

Ingliston Consols Extended G.M. Concentrates.—These appeared to be derived mainly from sulphide ore.

The minerals recognised under the microscope were :—Arsenopyrite, pyrite, carbonates, talc, sericite, quartz, rutile, sphene, tourmaline, zircon, epidote, magnetite, tennantite, and gold.

The following analytical results were obtained :—

Gold	1 oz. 19 dwts. 17 grs. per ton.
Silver	5 dwts. 2 grs. „
Platinum	*Nil*
Sulphur	20·94 per cent.
Arsenic	28·69 „
Iron, Fe	28·59 „
Iron oxide, FeO	4·90 „
Nickel	·36 „
Copper	traces
Silica	3·54 „
Lime	1·06 „
Magnesia	4·19 „
Alumina	1·72 „
Titania	·23 „
Carbonic acid	4·38 „
Water, alkalis, etc.	1·40 „
	100·00 „

Chemical analysis pointed to the presence of calcite and mesitite, and confirmed the presence of small amounts of tennantite, also the absence of any other sulphide than those recognised under the microscope.

The approximate mineral composition of the concentrates is—

Specific Gravity 3·0 and over	Arsenopyrite	62·4	per cent.
	Pyrite	16·2	„
	Limonite and Rust	3·9	„
	Rutile	·2	„
	Magnetite, Sphene, Zircon, Tourmaline, Epidote, Tennantite	traces	
	Mesitite	7·6	„
Specific Gravity under 3·0	Calcite	1·9	„
	Serpentine and Chlorite	3·7	„
	Talc	1·4	„
	Sericite	1·7	„
	Quartz	1·0	„
		100·0	

Analyst : H. Bowley.

Commodore G.M. Concentrates.—These were quite different from those previously described in that they contained only a very small proportion of metallic sulphides, and assayed low in gold. They resemble rather unconcentrated sands.

The minerals detected under the microscope were :—Quartz, carbonates, brown iron ore partly pseudomorphous after pyrite, arsenopyrite, pyrite (in pyritohedra and in cubes modified by the pyritohedron), fuchsite, rutile, chromite, apatite, and gold. Blowpipe tests showed that whilst most of the brown iron ore was turgite, the pseudomorphs were limonite.

A chemical analysis yielded the following results :—

Gold	3 dwts. 6 grs.	per ton.
Silver	1 dwt. 2 grs.	,,
Sulphur	1·34	per cent.
Arsenic	1·20	,,
Iron, Fe	1·62	,,
Iron protoxide, FeO	4·01	,,
Iron sesquioxide, Fe_2O_3	11·46	,,
Silica	55·04	,,
Lime	2·08	,,
Magnesia	7·56	,,
Manganese oxide	·43	,,
Alumina	3·80	,,
Titania	·25	,,
Carbonic acid	9·30	,,
Copper	·30	,,
Chromium oxide	·21	,,
Phosphoric oxide	trace	
Water, alkalis, etc.	1·40	,,
	100·00	,,

The absence of any sulphide other than those recognised under the microscope was proved, as also the presence of malachite, ilmenite, and rutile, mesitite and dolomite.

The mineral composition was calculated to be :—

Minerals with Specific Gravity 3·0 and over	Arsenopyrite	2·6	per cent.
	Pyrite	1·6	,,
	Malachite	·4	,,
	Turgite and Limonite ..	12·1	,,
	Rutile	·1	,,
	Ilmenite	·3	,,
	Chromite	·3	,,
	Gold, Apatite	traces	
	Mesitite	12·9	,,
Minerals with Specific Gravity under 3·0	Dolomite	6·8	,,
	Serpentine and Chlorite ..	7·0	,,
	Talc	1·6	,,
	Fuchsite and Sericite ..	5·6	,,
	Quartz	48·7	,,
		100·0	,,

Analyst : H. Bowley.

Kyarra G.M. Concentrates.—Several very small packets of concentrates produced by hand washing from single dishes of oxidised ore were submitted by Mr. Clarke. These were too small for very detailed examination. The results obtained are tabulated below.

No.	7767,	7768,	7769,	7770.
Source.	Main ore body.	Tailings dump.	North ore body.	30ft. Level.
	%	%	%	%
Arsenopyrite and Pyrite ..	2·0	..	..	..
Carbonate (Ankerite?) ..	..	little	little	little
Iron scale	68·2	·4	15·0	30·2
Iron hydrates	8·3	17·8	21·9	33·5
Talc	..	little	little	..
Sericite	..	4·4	little	..
Quartz	21·5	77·2	63·1	5·1
Asbestos	..	..	..	little
Zircon	..	little	..	..
Scorodite ?	..	·2	little	..
Native Gold	little	little	little	31·2
	100·0	100·0	100·0	100·0

In two of these concentrates a little As_2O_5 was detected, and this is tentatively ascribed to the presence of scorodite (hydrous ferric arsenate) which is the commonest arsenate occurring in auriferous quartz reefs throughout Australia.

1st July, 1916.

CHAPTER IX.

THE UNDERGROUND WATERS OF THE MEEKATHARRA AREA.

By E. S. Simpson.

During Mr. E. de C. Clarke's survey of the Meekatharra Area in 1914/5, eleven typical samples of underground waters were collected and subsequently analysed in the Geological Survey Laboratory. The results of these analyses are given in the accompanying tables, together with the results of analyses of two other waters from the same district made in previous years, and one made just recently. The complete list is as follows:—

[5372.] Kyarra Gold Mine,* Garden Gully. Rock, chlorite schist (sheared dolerite), with quartz veins.

[7233.] Mines Water Supply Well, No. 3, Water Reserve 10663, Garden Gully. Rock, weathered chlorite schist.

[7234.] Mixed water from Mines Water Supply, Wells Nos. 3 and 5, Water Reserve 10663, Garden Gully. Rock, weathered chlorite schist. Eighteen million gallons were drawn from four adjacent wells, between 1st July, 1914, and 1st July, 1915.

[1274.] Well on State Battery Reserve 9142, Meekatharra. Rock, altered peridotite near junction with sheared dolerite on east side; porphyry dyke at short distance to west.

[2085.] Shaft, Commodore North Gold Mine, Paddy's Flat, Meekatharra. Now drained dry by Commodore Mine. Rock, junction of altered peridotite with sheared dolerite, near albite-porphyry dyke.

* The position of these mines and wells is shown on Plate XXI.

[7052.] 300ft. Level, West Lode, Commodore Gold Mine, Paddy's Flat, Meekatharra. Rock, quartz veins in sheared dolerite (carbonated), close to junction with fuchsite-mesitite rock. Supply, about 15,000 gallons a day.

[7051.] 400ft. Level, East Lode, Commodore Gold Mine, Paddy's Flat, Meekatharra. Rock, lode close to junction of sheared and carbonated dolerite with fuchsite-mesitite rock. Supply about 4,000 gallons a day.

[6925.] Main West Crosscut at 425 feet, Ingliston Extended Gold Mine, Paddy's Flat, Meekatharra. Rock, altered peridotite, close to junction of fuchsite-mesitite rock and sheared peridotite, near dyke of porphyry.

[6715.] Drive at 450 feet, Queen of the Hill Gold Mine, Paddy's Flat, Meekatharra. Water from lode along fault, with jasper on one wall, and fine sheared dolerite and altered peridotite on the other.

[6974.] No. 2 Level, off new Main Shaft at 320 feet, Marmont Gold Mine, Paddy's Flat, Meekatharra. Rock, quartz porphyry, near contact with peridotite schists.

[6924.] 210ft. Level, close to Main Shaft, Globe Gold Mine, south of Paddy's Flat, Meekatharra. Rock, fuchsite-mesitite rock. Supply about 6,000 gallons a day.

[6793.] 170ft. Level in Main Shaft, Rocklee Gold Mine, Yaloginda. Rock, soft greenstone schist (sheared amphibolite).

[9279.] Well on Domestic Water Supply, Reserve 13931, 4½ miles E.N.E. of Meekatharra. Rock, granite wash overlying greenstone, close to large area of granite. Four million gallons were obtained from the wells on this Reserve between 1st July, 1914, and 1st July, 1915.

Meekatharra is situated in latitude 26½° south on the great central plateau of Western Australia, near its highest point. The mean elevation of the district is about 1,700 feet above sea level; the highest point near the township reaching to 1,800 feet, and the surface falling to 1,550 feet at a distance of 10 miles to the south-west. About the site of the town itself is an appreciable water-shed between the usually dry stream beds leading on the south-east side to the inland basin of Lake Annean, and on the north-west side to the Upper Murchison River and thence ultimately to the sea, from which Meekatharra is distant about 280 miles in a direct line.

Of the contour of the undulating surface constituting the water level underground (the water table), little is known except that at times its slope is quite different to that of the ground surface. Thus between the Domestic Water Reserve and the

Marmont Mine, there is a surface rise towards the latter of about 30 feet, but a fall in the underground water level of about 70 feet.*

The average rainfall is low, viz., 10.57 inches for the period of 1909/15. At the same time, it is very irregular, several inches of rain falling occasionally in a few days, and the yearly fall varying from 4.87 to 20.31 inches. The evaporation must be enormous. No actual figures are available for this centre, but in others similarly situated on the central plateau, it varies from 80 to 160 inches per annum. Under such conditions, there is no surface water, except at rare intervals; the water level underground is usually below 100 feet in depth and only rarely does any large quantity of meteoric water penetrate into the underground supply.

The geological structure has been worked out by Mr. Clarke. It consists in the main of a very ancient complex of igneous rocks, comprising granitic, doleritic and peridotitic types, all in places massive, in others more or less highly sheared and to a considerable extent carbonated in certain zones. Associated with these are some ancient, Devonian?, sediments. The igneous rocks are traversed by jasper bars, and also by quartz reefs and shear zones containing gold and with it below water level, a comparatively small proportion of pyrite and arsenopyrite. The plane of schistosity agrees with the strike of the lodes and some smaller more compact dykes, being N. 40° E., in which direction the underground waters are most free to flow, whilst at right angles to it, their movement is barred almost completely. Except for the recent surface loess and alluvium, there appear to be no post-paleozoic sediments in the immediate vicinity and no certain evidence that any part of the adjacent country has been submerged beneath the ocean since Devonian or Carboniferous times.

The only remaining factor affecting the composition of the underground water is the vegetation. Of this very little information is available. The most conspicuous plant, however, is the shrub known as mulga, a variety of Acacia (Ord. *Leguminosae*). Smaller leguminous plants are also doubtless present. The late Dr. Morrison, Government Botanist for the State, was of opinion that the Acacias and other native leguminous plants had an appreciable effect in stimulating, through associated micro-organisms, the processes of nitrification in the soil. At the same time, nitrification is found to proceed rapidly in other parts of the interior now under wheat cultivation and entirely cleared of all leguminous plants. On the other hand, nitrates are absent from the waters on the goldfields of the central plateau, south of 30 deg. south latitude, where there is apparently a balance between the amount of nitrates produced in the soil by micro-organisms and that utilised by the higher plants growing in association with

* For further figures regarding this see Mr. Clarke's Table on page 32.

them. In the Murchison Area this balance does not appear to prevail, more nitrates being produced in the soil than can be absorbed by the vegetation. In this way only does it appear possible to account for the abundance of nitrate ion in the underground waters over a large area which embraces Meekatharra within its boundaries.

The waters, as they now stand, are undoubtedly mixtures and their contained solids may be traced to various origins. Of these the chief seem to be:—

(1.) Residual oceanic water, carrying normal oceanic salts (cyclic salts). These in decreasing order of importance, are sodium chloride, magnesium chloride, magnesium sulphate, calcium sulphate, potassium chloride and calcium carbonate.

(2.) Rainfall of present and past ages, carrying carbonic acid, oxygen and cyclic salts, the last named in very small total proportion, but in approximately the same relative proportion as the oceanic waters from which the rain was derived.

(3.) Soluble nitrates formed in the top layers of the soil by micro-organisms, dissolved in the rain water and carried into the underground supply.

(4.) Soluble products of decomposition and direct solution by rain water of the rocks and their contained lodes. These are mainly carbonates of calcium, magnesium, sodium, and potassium, with smaller quantities of sulphates of the same. Sulphates of iron are only formed transiently from pyrites as they are rapidly precipitated by the superabundant carbonates and oxygen.

(5.) Residual magmatic waters given off by the cooling of masses of igneous rocks and containing in the early stages a large number of constituents, but as cooling proceeds probably mainly salts of the alkalies together with carbonic acid.

To what extent each of these sources has contributed to the present mixtures it is impossible to say, since any one component, such as for example sodium, may be common to two or more of them, and, further, the commingling of waters from different sources invariably leads to precipitation, leaving in solution something which is not the sum of the two original constituents. Although the details of this latter change cannot be traced, the general lines upon which it proceeds are beyond doubt, because of the known solubilities of the simple products of interaction of the limited number of ions in the various contributing solutions.

All chlorides are freely soluble in water except the normal chlorides and basic chlorides of certain heavy metals, *e.g.*, copper and silver. Unless, therefore, enormous quantities of these heavy metals occurred in this region, and we know they do not, chlorine ion is never removed from the water by precipitation in appreciable amounts, but on the contrary it accumulates and its total constantly increases with each addition of rain or other water. Similarly all common salts of sodium being freely soluble, sodium ion also accumulates. With the possible exception of nitrate ion these are the only components of the waters of which this can be said. Turning to Table III. it will be found that chlorine and sodium ions between them account in one case for as much as 75 per cent. of the total solid matter, and are seldom less than 50 per cent.

At the other extreme is iron. Although the freely soluble ferrous sulphate is a first product in the weathering of the pyrites contained in the rocks and lodes, and the moderately soluble ferrous bicarbonate in the weathering of the rock forming silicates, both oxidise and hydrolyse readily with the formation ultimately of the very insoluble ferric hydroxide (limonite, etc.). This action is promoted by the abundant dolomite, magnesite, etc., in the rock masses, which prevent the water from developing acidity. Hence there is no accumulation of iron and the waters show only traces of it present.

Considerable quantities of potassium salts, all of which are freely soluble, must dissolve in the water during its history, but since this metal readily forms several insoluble secondary silicates such as sericite, glauconite, and various zeolites, it is never allowed to accumulate to any great extent. Secondary sericite is as a matter of fact abundant in the sheared rocks of the district. That potassium may temporarily be a somewhat important constituent of a water with restricted movement is shown by the analysis of water from the east lode in the Commodore Mine, in which potassium amounts to 9.80 of the total solid matter. In almost all the other waters it is well below one per cent.

The carbonates and bicarbonates of such widespread and abundant metals as calcium and magnesium are only slightly soluble, so that the monocarbonate ion in these, as in other waters, never rises to a high amount. Sulphates of magnesium and calcium are more freely soluble, but the presence of secondary calcite, dolomite, and gypsum throughout the water-bearing zone point to the continual removal of calcium, magnesium and sulphate ion by the water when it reaches saturation point for those compounds, a point which is reached at a comparatively small concentration.

Bearing in mind this general course of precipitation it is readily understood why in all the waters from this area sodium is the dominating positive ion, chlorine the dominating negative ion;

sodium chloride thus constituting slightly more than one half of the total solids obtained from eight of the waters and only slightly less than one half in the remaining six.

The next most important ions are magnesium and sulphate ions, magnesium sulphate being in all cases but one the next most important component of the solid matter. Other less important but ever present compounds are magnesium chloride and calcium carbonate. Magnesium carbonate appears in the solid matter obtained by evaporation from all but three of the waters, and sodium nitrate in all but two. This latter constituent whilst freely distributed throughout the Murchison Area of this State, is a very unusual constituent of mineral waters elsewhere. Its origin has already been dealt with.

In sea water sodium chloride forms nearly three-quarters of the total solids whilst the other common salts in decreasing order of importance are magnesium chloride, magnesium sulphate and calcium sulphate. Nitrates are absent.

The general character of the waters, as a whole, may, therefore, be summed up as weakly alkaline and saline of the oceanic type, with the addition in most cases of important amounts of nitrates.

The water samples were derived from wells and shafts at four different centres, Garden Gully, Paddy's Flat, the Domestic Water Supply Reserve and Yaloginda. Of these, Garden Gully is eleven miles N.N.W. of Meekatharra township, Paddy's Flat immediately east of it, the Domestic Supply Reserve four and one-half miles to the north-east, and Yaloginda six miles to the south-west. On the score of locality, therefore, they have been divided into four series.

Garden Gully Series.—This comprises the waters from the shaft of the Kyarra Mine and from two wells used to supply the mines with water for milling. No. 5 Well is slightly over a mile south-west of the Kyarra Mine, whilst No. 3 Well lies between the two. All three shafts are in a sheared and altered dolerite underlying a flat valley with a fall to the west. The composition of the Kyarra water might be expected to be influenced by the presence of ore bodies, which are absent in the case of the other two wells. The prevailing N.N.E. strike of the shearing planes debars any free circulation of water between the mine and the two wells to the west, in proof of which Mr. Clarke informs me that the unwatering of the mine had no effect upon the water level in the two wells.

Tables I., II. and III. indicate an almost complete identity in the water from Wells 3 and 5, but that from the Kyarra is 50 per cent. more saline, and there is an appreciable difference

in the relative proportions of most of the ions, which is brought out more clearly in the table in which these have been calculated to salts. Calcium and magnesium are almost equal in all three, the latter slightly predominating. The nitrate ion is very similar and moderately low. The total salts are sufficiently low in all three to make the waters only slightly brackish.

Economically, these waters would be looked upon as good stock water, and suitable for gold milling or cyaniding. As boiler waters they would be corrosive and yield considerable scale unless softened previous to use.

Paddy's Flat Series.— These waters are all taken from gold mining shafts and drives and, with the exception of the water from the Globe Mine, are derived from a very restricted area of about one and a half miles long by one mile wide. The Globe Mine is two miles to the S.S.W. on the prevailing line of strike.

In spite of the restricted nature of the area from which these waters are derived, there are quite marked differences between the waters. Thus the total solids vary from 0.1097 per cent. in the very fresh water at the Commodore North Mine to 1.3513 per cent. in the salt water from the Marmont Mine, distant one and a quarter miles away on a surface contour only 30 feet lower, but from a deeper shaft. Other differences are brought out most clearly by Table III., which, neglecting the degree of concentration, brings out any differences in the relative proportions of the metals and radicles forming the dissolved solid matter.

The wide variation in the nitrates present is evidenced by the figures for the nitrate ion, NO_3, which vary from nil in the water from the Fenian Mine to 12.41 per cent. of the total solids, equal to 17.0 per cent. of sodium nitrate, in that from the West lode of the Commodore Mine. Mr. Clarke informs me that this latter lode channel is a very porous one with many vughs, which would amply explain the low concentration of salts in the water and the high relative proportion of nitrate, both being due to free infiltration of rain water. The greatest actual concentration of nitrates is in the water from the Marmont Mine, which contains 25.34 grains sodium nitrate per gallon (0.0362 per cent.). This is the largest amount ever found in any water in the State.

Most noticeable is the difference between the two waters from the Commodore Mine, collected from two parallel lodes only 100 feet apart. This is most prominent in the figures for total salinity, nitrate ion, carbonate ion, potassium, and calcium. There is evidently no free circulation between these two lodes through the small intervening mass of doleritic schist.

Very marked again are the differences between the waters from the Fenian and Marmont Mines obtained from shafts less than

ten chains apart and on the same general strike of country. The Marmont water is nearly twice as saline as that from the Fenian, and is quite different in the relative proportions of nitrates, calcium, and magnesium.

With these facts before one, one is driven to the conclusion that even in the restricted area of Paddy's Flat there is no free underground circulation of the text book type, but on the contrary even along the lines of foliation the movement is small and slow, and across them and across the occasional compact dykes of porphyry and little altered dolerite it is almost *nil.*

No definite relationship has been established between the composition of the waters in this area and the enclosing rock, which in most cases is a complex of much altered dolerite and peridotite.

Domestic Supply Series.—The wells from which the supply of domestic water for Meekatharra is obtained are all within a small area, and are sunk in permeable granite debris. Their total salinity is less than that from any other part of the area under review. Samples from Nos. 2 and 3 wells, taken on the same day and analysed by the Government Analyst, were identical with one another, and except in degree of concentration with that from No. 1 well taken six months earlier, an unusually rainy winter intervening, and from one of the wells taken eight months later (9279). To the porous nature of the ground which permits of ready penetration of rain water, and to the shallow water level (30 feet) and general situation, which does not permit of accumulating drainage from low-lying saline water levels, must be ascribed the unusual purity of the water in this locality. The water contains a notable amount of sodium nitrate, derived from the soil in the immediate vicinity; but for this it would be an excellent drinking water.

Yaloginda.—A single sample of water was collected at this locality. It is low in total salinity, approaching in this respect the waters from the Kyarra Mine, at Garden Gully, and from the Commodore and Queen of the Hill Mines, at Paddy's Flat. Like the water from the Fenian Mine it is, however, exceptional in being devoid of nitrates. With this exception it is very like the water from the west lode of the Commodore Mine.

Although said to be used for drinking purposes this water is not suited for that purpose or for boilers, unless previously softened. It is quite pure enough for all other mining purposes.

Resumé.

The waters of the Meekatharra district are all of the same general type, being solutions in varying concentration of the common cyclic salts, derived probably from residual ocean waters and from rain, as well as from local weathering of rocks and pyritous

lodes, to which has been added an unusual constituent in the shape of sodium nitrate, formed by bacterial activity in the surface soil, and carried down by percolating rain water. The extent of the influence of residual magmatic water cannot be defined.

The waters from four distinct localities have been examined. Of these, three, viz., Garden Gully, Yaloginda, and the Domestic Water Reserve, yield waters which are fresh, or at most only slightly brackish. The fourth locality, Paddy's Flat, is the centre of considerable gold-mining activity, and within a small area yields waters of a wide range of salinity from quite fresh to distinctly salt, and with somewhat marked variations in the relative proportions of the different constituents.

The circulation of the water underground in this area is slow and restricted even in the direction of the prevailing foliation. At right angles to this it must be almost negligible.

The variations within the same general type of water cannot be explained by reference to the unweathered enclosing rocks, but appear to be due rather to varying porosity of the zone of weathering which permits a variable penetration of rain water with its accompanying cyclic salts and salts leached from the soil and weathering rock, followed by unequal precipitation of the less soluble components and differing degrees of evaporation. In conjunction with this there is the greater or less restricton of underground movement, which would tend ultimately to a concentration of salts in the lower lying portions of the undulating surface of the water level throughout the district.

1st June, 1916.

TABLE I.—MEEKATHARRA WATERS.

Composition expressed in Salts in parts per hundred of water.

Series	Garden Gully.			Paddy's Flat.									Yalo-ginda.	Domestic Supply.
No.	5372.	7233.	7234.	1274.	2085.	7052.	7051.	6925.	6715.	6716.	6974.	6924.	6793.	9279.
Source	Kyarra G.M.	Well 3, W.R. 10663.	Wells 3 and 5, W.R. 10663.	State Battery Well.	Com-modore North G.M.	Com-modore G.M. West Lode.	Com-modore G.M. East Lode.	Ingliston Ex-tended G.M.	Queen of the Hill G.M.	Fenian G.M.	Mar-mont G.M.	Globe G.M.	Rocklee G.M.	Well on W.R. 13931.
Calcium carbonate .. $CaCO_3$	·0282	·0186	·0182	·0271	·0084	·0091	·0073	·0084	·0175	·0150	·0335	·0232	·0221	·0107
Magnesium carbonate $MgCO_3$	..	·0102	·0111	..	·0126	·0121	·0301	·0192	·0098	..	·0078	·0076	·0117	·0046
Iron carbonate .. $FeCO_3$	..	..	..	..	·0002	..	..	..	..	..	..	..	..	..
Calcium sulphate .. $CaSO_4$	·0026	..	..	·0177	..	..	..	..	..	·0568	..	..	..	..
Magnesium sulphate $MgSO_4$	·0380	·0262	·0245	·1243	·0204	·0209	·0143	·0612	·0528	·1179	·2825	·1575	·0441	·0119
Sodium sulphate .. Na_2SO_4	..	..	..	..	..	..	..	..	..	..	..	..	·0041	..
Potassium sulphate .. K_2SO_4	..	..	..	..	..	..	·0300	..	..	..	..	..	·0013	·0013
Sodium nitrate .. $NaNO_3$	·0076	·0069	·0056	·0231	·0104	·0204	·0111	·0214	·0157	*Nil*	·0362	·0188	*Nil*	·0093
Magnesium chloride $MgCl_2$	·0226	·0023	·0031	·1540	·0093	·0059	..	·0411	·0188	·0918	·2655	·0654	..	..
Sodium chloride .. $NaCl$	·1199	·0819	·0819	·3296	·0422	·0453	·0645	·1172	·1216	·5851	·7022	·4176	·1182	·0432
Potassium chloride .. KCl	·0097	·0027	·0034	·0036	·0016	·0013	·0053	·0006	·0022	·0074	·0192	·0053	..	·0002
Sodium bromide .. $NaBr$	..	..	..	..	*Nil*	..	..	..	..	..	..	..	..	..
Sodium iodide .. NaI	..	..	..	..	*Nil*	..	..	..	..	..	..	..	..	..
Alumina (Iron oxide) Al_2O_3 (Fe_2O_3)	·0006	·0002	·0003	·0004	·0011	·0010	·0005	·0004	·0002	·0002	·0005	·0003	·0006	·0003
Boric oxide .. .. B_2O_3	..	..	..	..	Strong trace	..	..	..	..	..	..	..	..	..
Phosphoric oxide .. P_2O_5	..	..	..	Trace	·0001	..	..	..	..	..	..	..	..	..
Silica .. .. SiO_2	·0050	·0039	·0062	·0046	·0034	·0041	·0033	·0020	·0034	·0016	·0039	·0038	·0028	·0064
Total Solids	0·2342	0·1559	0·1543	0·6844	0·1097	0·1201	0·1664	0·2715	0·2420	0·8758	1·3513	0·6995	0·2049	0·0879
Extra CO_2	..	·0141	·0156	..	·0091	·0107	·0183	·0127	·0163	·0078	·0240	·0166	·0192	..
Date of Sampling	XI.—13	I.—15	I.—15	VIII.–05	VI.—06	XII.—14	XII.—14	XI.—14	X.—14	X.—14	X.—14	XI.—14	X.—14	VI.—16
Analyst	H.B.	H.B.	H.B.	E.S.S.	E.S.S.	H.B.	H.B.	H.B.	E.S.S.	E.S.S.	H.B.	H.B.	H.B.	H.B.

TABLE II.—MEEKATHARRA WATERS.

Composition expressed in Ions in parts per million of water.

Series		Garden Gully.			Paddy's Flat.									Yaloginda.	Domestic Supply.
No.		5372.	7233.	7234.	1274.	2085.	7052.	7051.	6925.	6715.	6716.	6974.	6924.	6793.	9279.
Source		Kyarra G.M.	Well 3, W.R. 10663.	Wells 3 and 5. W.R. 10663.	State Battery Well.	Commodore North G.M.	Commodore G.M. West Lode.	Commodore G.M. East Lode.	Ingliston Extended G.M.	Queen of the Hill G.M.	Fenian G.M.	Marmont G.M.	Globe G.M.	Rocklee G.M.	Well on W.R. 13931.
Chloride ion	Cl	941	527	536	3,163	333	325	416	1,020	888	4,268	6,328	3,045	717	263
Sulphate ion	SO_4	321	209	196	1,117	163	167	279	488	421	1,342	2,254	1,257	387	102
Nitrate ion	NO_3	55	50	41	168	76	149	81	156	115	*Nil*	264	137	*Nil*	68
Phosphate ion	PO_4	..	..	..	Trace	1	..	..	..	..	..	..	..	..	..
Carbonate ion	CO_3	169	185	188	163	141	141	258	187	175	90	257	193	215	97
Biborate ion	B_4O_7	..	..	..	..	Strong trace	..	..	..	..	..	..	..	..	..
Sodium ion	Na	493	341	337	1,360	194	233	284	519	520	2,302	2,860	1,694	478	195
Potassium ion	K	51	14	18	19	8	7	163	3	12	39	101	28	6	7
Calcium ion	Ca	121	74	73	160	34	36	29	34	70	227	134	93	89	43
Magnesium ion	Mg	135	88	89	644	101	92	116	284	183	472	1,271	507	123	37
Iron ion	Fe	..	..	..	..	·1	..	..	..	..	..	..	..	..	..
Alumina (Iron oxide)	Al_2O_3 (Fe_2O_3)	6	2	3	4	11	10	5	4	2	2	5	3	6	3
Silica	SiO_2	50	69	62	46	34	41	33	20	34	16	39	38	28	64
Total Solids		2,342	1,559	1,543	6,844	1,097	1,201	1,664	2,715	2,420	8,758	13,513	6.995	2,049	879
Extra carbon dioxide, CO_2		..	141	156	..	91	107	183	127	163	78	240	166	192	..

TABLE III.

MEEKATHARRA WATERS.

Percentage Composition of Solid Matter.

Series ..	Garden Gully.			Paddy's Flat.									Yalgoginda.	Domestic Supply.
No. ..	5372.	7233.	7234.	1274.	2035.	7052.	7051.	6925.	6715.	6716.	6974.	6924.	6793.	9279.
Source ..	Kyarra G.M.	Well 3, W.R. 10663.	Wells 3 and 5, W.R. 10663.	State Battery Well.	Commodore North G.M.	Commodore G.M. West Lode.	Commodore G.M East Lode.	Ingliston Extended G.M.	Queen of the Hill G.M.	Fenian G.M.	Marmont G.M.	Globe G.M.	Rocklee G.M.	Well on W.R. 13931.
Cl ..	40·18	33·80	34·74	46·21	30·36	27·06	25·00	37·57	36·70	48·73	46·83	43·53	34·98	29·92
SO_4 ..	13·70	13·41	12·70	16·32	14·86	13·90	16·77	17·97	17·40	15·32	16·68	17·97	18·89	11·60
NO_3 ..	2·35	3·21	2·66	2·45	6·93	12·41	4·87	5·75	4·75	*Nil*	1·95	1·96	*Nil*	7·74
PO_4 ..	..	..	..	Trace	·09	..	..	..	..	..	..	..	..	..
CO_3 ..	7·21	11·86	12·18	2·38	12·85	11·74	15·50	6·89	7·23	1·03	1·90	2·76	10·49	11·04
B_4O_7 ..	..	..	..	..	Traces	..	..	..	..	..	..	..	..	..
Na ..	21·05	21·87	21·84	19·87	17·68	19·40	17·07	19·12	21·49	26·29	21·16	24·22	23·33	22·18
K ..	2·18	·90	1·17	·28	·73	·58	9·80	·11	·50	·45	·75	·40	·30	·80
Ca ..	5·17	4·75	4·73	2·34	3·10	3·00	1·74	1·25	2·89	2·59	·99	1·33	4·34	4·89
Mg ..	5·76	5·64	5·77	9·41	9·21	7·66	6·97	10·46	7·56	5·39	9·41	7·25	6·00	4·21
Fe ..	..	..	..	..	·09	..	..	..	..	..	..	..	..	..
Al_2O_3 (Fe_2O_3) ..	·26	·13	·19	·06	1·00	·83	·30	·15	·08	·02	·04	·04	·30	·34
SiO_2 ..	2·14	4·43	4·02	·68	3·10	3·42	1·98	·73	1·40	·18	·29	·54	1·37	7·28
Total ..	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Salinity per million ..	2,342	1,559	1,543	6,844	1,097	1,201	1,664	2,715	2,420	8,758	13,513	6,995	2,049	879

INDEX.

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

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WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 69.

CONTRIBUTIONS

TO THE STUDY OF

THE GEOLOGY AND ORE DEPOSITS OF KALGOORLIE

East Coolgardie Goldfield.

PART III.

BY

F. R. FELDTMANN.

ISSUED UNDER THE AUTHORITY OF

THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH 14 PLATES AND 43 FIGURES.

PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1916.

j58/16

PREFATORY NOTE.

The present contribution forms the third of the series designed to deal more or less exhaustively with the Geology and Ore Deposits of Kalgoorlie.

It had been intended to include in this *Bulletin* the contribution by the Petrologist, Mr. Farquharson, but as such was not available at the time this was ready for Press it was not deemed expedient to delay the publication of the information regarding the ore bodies and mines of the North End. The petrological contribution will, it is hoped, appear later.

A. Gibb Maitland

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 1st August, 1916.

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* Serving with the Expeditionary Forces.

CONTENTS.

CONTENTS—*continued.*

LIST OF PLATES.

(In separate atlas).

LIST OF FIGURES.

LIST OF FIGURES—*continued.*

Contributions to the Study of The Geology and Ore Deposits of Kalgoorlie, East Coolgardie Goldfield.

PART III.

X.—THE GEOLOGICAL FEATURES OF THE "NORTH END," KALGOORLIE.

By F. R. FELDTMANN.

AUTHOR'S NOTE.

The writer takes this opportunity of acknowledging his indebtedness to Mr. Farquharson, on whose determinations the rock-classification adopted in this report has been mainly based, and whose friendly criticism on many points has proved of very great assistance.—F.R.F., 5th July, 1916.

INTRODUCTORY REMARKS.

The portion of the Kalgoorlie auriferous belt with which the present report is most chiefly concerned is that to the south of the area described by the writer in Bulletin 51,* and is roughly bounded on the north-west by the Kanowna Railway line, on the south-west by the Boulder Railway line, on the north-east by a line roughly parallel to and about 70 chains from the last, and on the south-east by the southern limit of the flat south of Mt. Gledden, this flat seeming to form the natural boundary between the "North End" and the main auriferous belt of Kalgoorlie.

The area between these boundaries has been mapped on a scale of 100 feet to the inch (Plate XIII.), permitting all the important geological features, including the ore deposits, to be shown in detail. In addition to this detailed map, one on a scale of 10 chains

* Contributions to the Study of the Geology and Ore Deposits of Kalgoorlie, Part II. by F. R. Feldtmann and R. A. Farquharson.

to the inch (Plate XII.), covering an area of about five square miles, has been prepared. This map shows, in addition to the main geological features—including the main lines of lode— contour lines at 10-feet intervals; as the railway bench-marks are the datum points on which these contours are based, a reduction of 107 feet has to be made to give the true height above sea-level. For this map, the contours shown on the map published by the Survey in 1902 have been thoroughly revised, while that portion south of the Kanowna Railway line, which has been mapped on a scale of 100 feet, has been recontoured, owing to the extreme accuracy required for the geological sections, prepared on scales of 100 feet, 50 feet, or even less, to the inch.

I would here like to record my thanks to the leaseholders and prospectors of the North End, without whose ready assistance, often at considerable personal inconvenience, I should not have been able to examine many of the mine workings within this area.

I. TOPOGRAPHY.

The main topographical features of the more southerly portion of the North End differ but little from those of the more northerly portion. On the whole the hills are more decided in outline and rise to a greater relative height above the surrounding country.

A prominent feature is the well-marked line of hills comprising Mt. Charlotte, Hannan's Hill, Cassidy Hill, and Mt. Gledden, immediately to the east of the Boulder Railway line and following the general N.N.W.-S.S.E. trend of the country. Unlike the higher hills of the northern area, these hills, which are almost entirely in quartz-dolerite greenstone, are not capped by laterite, which is by no means as common in this as in the previously described area. This fact may probably be accounted for by the steeper slope of the hills and the consequent greater rate of denudation.

II. THE ROCKS.

In the previous report* the writer considered it more than likely that the more southerly portion of the field would throw further light on the geology of the northern portion—this belief has been amply justified, the more numerous outcrops, extensive mine workings, and comparative freshness of many of the rocks enabling a more thorough and detailed classification to be made than was possible in the earlier report. Nevertheless, as compared with the great variety of the rocks, exposures in outcrops and mine workings are by no means as common as could be desired, particularly

* *Loc. cit.*, p. 10.

in the low-lying ground on which the town itself is situated, unweathered outcrops and mine-workings sufficiently deep to be of any use being here practically absent.

In the light of data now available the northern area was briefly re-examined and its rocks reclassified, the results being shown on the 10-chain map (Plate XII.), but the mapping of the ore deposits and other details shown on the 100-feet map is not affected by this revision. The detailed description of the rocks given in the following pages applies to the North End as a whole.

The present classification is based on the results of a detailed and thorough examination of the relationships of the rocks in the field, as well as the petrological examination by Mr. Farquharson of over 200 specimens collected by the writer, and also of many of those already in the Survey collection. In addition a number of fresh analyses have been made by Mr. E. S. Simpson, Mr. H. Bowley, and other members of the Laboratory Staff.

The present classification differs from that given in Bulletin 51 chiefly in the separation of the Older Greenstone series from the Younger or Intrusive series—which, owing to the paucity of exposures and lack of any marked differences in the specimens previously examined, was not possible when dealing with the more northerly area alone. Both Older and Younger Greenstones have been further separated into groups and sub-groups, many of which are unrepresented in the northern area.

The classification now adopted may be subject to criticism on account of its extreme detail, but it is justified by its exceedingly important economic bearing. In general it approaches most nearly to that given in Dr. J. A. Thomson's paper.*

*. "The Petrology of the Kalgoorlie Goldfield." Quart. Journ. Geol. Soc., Vol. xix., 1913, page 626.

Rocks of the "North End."

Original Rocks.		Present Form of Rocks.
1. Lavas (Older Greenstones) ..	Lavas	(*a*) Fine-grained amphibolites [epidiorites (*b*)]. (*b*) Fine-grained greenstones. (*c*) Calc-schists.
2. Intrusives— A Basic to ultrabasic (Younger Greenstones)	Quartz-gabbros or quartz-dolerites	(*a*) Amphibolites [epidiorites (*a*)]. (*b*) Greenstones. (*c*) Bleached greenstones. (*d*) Actinolite-zoisite amphibolites [epidiorites (*b*)] in part.
	Gabbros or dolerites	(*d*) Actinolite-zoisite amphibolites [epidiorites (*b*)] in part. (*e*) Greenstones.
	Hornblende-dolerites	(*f*) Lustre-mottled amphibolites.
	Pyroxenites	(*g*) Hornblendites. (*h*) Talc-chlorite-carbonate rocks.
	Peridotites	(*i*) Talc-mesitite rocks. (*j*) Serpentines.
	? (Various)	(*k*) Fuchsite-carbonate-quartz rocks.

Rocks of the "North End"—*continued.*

Original Rocks.		Present Form of Rocks.
B. Intermediate to acid ..	Hornblende-quartz-porphyrites ..	Hornblende-quartz-porphyrites.
	Albite-porphyrites	Albite-porphyrites.
3. Sediments	Sediments	Slaty beds.
4. Superficial deposits	.. ..	(*a*) Laterite. (*b*) Sand, loam, etc.
5. (Various)	.. ..	Jaspers and graphitic schists.

In the above classification and in the following pages the term greenstone is used in two ways: first in the usual broad sense as applied to the two main series of basic rocks—viz., the Older and the Younger or Intrusive Greenstones—when used in this sense a capital letter is employed; secondly as restricted by Thomson* to those rocks composed chiefly of chlorite and carbonates in place of the hornblende and saussurite of the amphibolites, as, for example, the quartz-dolerite greenstones. There should be no confusion between these two applications of the term.

It will also be noticed that the name epidiorite figures in the classification as an alternative name for some of the amphibolites. Some confusion seems to have arisen in the employment of the former term. The best classification of the epidiorites is that given in Teall's description of the geological structure of the North-West Highlands of Scotland.† Here he says:

''They'' (the epidiorites) ''may be roughly separated into two groups according to the presence or absence of the structure characteristic of the gabbros, diabases, and hyperites. In the first group (a) the lath-shaped or interstitial character of the felspar-sections is in most cases well marked, and the characteristic inclusions so common in the felspars of the diabases are often present. The hornblende is of two types. There is the compact green hornblende, similar to that of the hornblende-diabases, and also the fine-grained and sometimes fibrous aggregates which appear to eat into and finally destroy the original augite. Cores of augite may frequently be detected in the centres of these hornblende-aggregates, a little interstitial quartz is often present. . . . . The typical rocks of the second group (b) of epidiorites are devoid of igneous structure. They are essentially composed of plagioclase and hornblende, with which some quartz and a mineral of the epidote group are often associated. The felspar occurs as irregular grains or in large ophitic patches; sometimes as granular aggregates. It is in general more allied to albite than the felspar of the pyroxenic rocks. Not unfrequently it is crowded with minute prisms and grains of epidote, thus forming the typical saussurite of Cathrein. Under these circumstances it is either albite or some closely allied felspar. The hornblende may be either pale or dark green. It occurs as spongy aggregates enclosing rounded grains of quartz, as compact irregular individuals, and as aggregates with ragged outlines from which prisms often jut out into the surrounding felspar. Detached grains and prisms often occur as inclusions in the felspar. Biotite and iron-ores zoned with colourless granular sphene are frequently present.''

In the classification of the North End rocks the epidiorites fall into two groups, (a) and (b), as classified by Teall.

In order that the relationships between the various subdivisions of the Older Greenstones and the gabbroid or doleritic members of the Younger Greenstones, and the successive degrees of alteration,

* *Loc. cit.*, p. 630.

† Memoirs of the Geol. Surv. of Great Britain, 1907, p. 92.

may be more clearly understood, it may be advisable to present a portion of the classification in the following form:—

Original Rocks ..	Lavas	Quartz-gabbros or Quartz-dolerites	Gabbros or Dolerites	Hornblende-dolerites.	Pyroxenites.
Amphibolitic Stage	Fine-grained amphibolites	Quartz-dolerite amphibolites	(Unrepresented in this area)	Lustre-mottled amphibolites	Hornblendites
Greenstone Stage..	Fine-grained greenstones	Quartz-dolerite greenstones	Dolerite greenstones	(Unrepresented)	Talc-chlorite-carbonate rocks
Bleached Stage ..	Calc-schists	Bleached greenstones	Fuchsite-carbonate-quartz rocks (in part)	(Unrepresented)	Fuchsite-carbonate-quartz rocks (in part)

A parallel series of changes has taken place in the peridotites, for we have serpentines, talc-mesitite rocks with, probably, some of the fuchsite-carbonate-quartz rocks as the third stage of alteration.

This grouping according to the various stages of alteration does not necessarily imply that the more altered rocks have passed through all the intermediate stages, for it is possible that some of the greenstones may have been derived directly from the original rocks without passing through the amphibolitic stage. This question, however, will be gone into more thoroughly later on.

When describing each rock type in detail it will be stated whether, or no, the rock is of economic importance—this statement refers only to the occurrence or non-occurrence of payable deposits in the rock and not to the part it may have played in the introduction of the auriferous solutions.

1. The Older Greenstones.

Within the limits of the 10-chain map (Plate XII.) the rocks of this series occupy two large areas, namely, to the west and east of the main dyke of Intrusive Greenstone described later. The full extent of the western area has not been mapped—its eastern boundary appears to run roughly parallel to and about seven chains east of the Menzies Railway line; it is probably composed entirely of fine-grained amphibolites. Under the townsite of Kalgoorlie it is entirely obscured by superficial deposits and its southern extension could not be traced—specimens occur on the dump of the former Red Hill Extended (G.M.L. 64E) main shaft, but whether this occurrence represents an isolated area or part of the main western belt it is impossible to say. These rocks certainly do not form the wide continuous belt shown on Mr. Gibson's map,* for close examination has

* Contributions to the Study of the Geology and Ore Deposits of Kalgoorlie, Part I., by E. S. Simpson and C. G. Gibson. G.S.W.A., Bulletin No. 42, Plate II.

shown the presence of outcrops of quartz-dolerite amphibolite, actinolite-zoisite-amphibolite, and quartz-dolerite greenstone at the corner of Harley and Hinemoa Streets, west of Mullingar. Moreover petrological determination of the municipal quarry rock at Mullingar shows it to be a dolerite-greenstone and not one of the Older Greenstones.

The eastern belt is of great width, averaging probably between 60 and 70 chains; it also is largely obscured by superficial deposits. The northern portion of this belt appears to consist entirely of fine-grained amphibolites, which pass gradually into fine-grained greenstones to the south.

Unweathered outcrops are not common in either of these two belts, and the fine-grained amphibolites are exposed only on a few, usually weathered, dumps in addition to the very meagre outcrops. The fine-grained greenstones are fairly well exposed on dumps and to some extent in mine workings in the south-eastern portion of the area. The calc-schists are but poorly represented in this area, occurring only as local modifications of the fine-grained greenstones; they reach a very much greater development on the "Golden Mile."

The original form of the Older Greenstones is obscure, owing to the absence of relict-structures. In the majority of cases these rocks are exceedingly fine in grain, of intermediate-basic composition in those specimens which have been analysed, being apparently slightly more acid in composition than the quartz-dolerite derivatives, and in a few instances present the appearance of a fine-grained flow dolerite under the microscope. As Thomson states,* it would be possible to consider them as the altered chilled margins of the Intrusive Greenstones, were it not for their great extent, for it is almost impossible to distinguish between some of the fine-grained amphibolites and certain altered forms of the Intrusive Greenstones. On the bulk of the evidence it seems most probable that they represent original flow lavas; in the specimens examined no evidence was found of an original tufaceous rock.

(a) *The Fine-Grained Amphibolites.*

As already stated, within the limits of the 10-chain map, these rocks appear to occupy the whole of the western belt, and the northern and slightly larger half of the eastern belt of Older Greenstones. On the evidence of isolated dumps, the eastern boundary of the western belt runs through M.H.L. 83E, at the north-west corner of the map, southwards through M.H.L. 200E, to pass close to the eastern boundary of the former Monte Carlo G.M.L. 1249E. South of this it cannot be traced, but, as previously stated, specimens were found on the former Red Hill Ex. dump, west of Cassidy Hill

* *Loc. cit.*, p. 631.

and the Boulder Railway line. Still further south, and beyond the limits of the map, typical specimens occur on a dump near the north corner of G.M.L. 4370E (formerly part of G.M.L. 942E, Queen of the West), near the Boulder Road, and 11 chains west of Kallaroo Station. These rocks do not appear to extend further south for any great distance.

The western boundary of the eastern belt is obscured near the northern limit of the map. It probably crosses the Broad Arrow Road near the North corner of the former Sir John G.M.L. 4468E, to follow the north-eastern boundary of that lease fairly closely and cross the Kanowna Railway line about two chains east of the western corner of the North Collier; thence it crosses the Transcontinental Railway line rather more than a chain east of the north-eastern boundary of the old Devon Consols mine and runs on through the North End Ex. G.M.L. 4485E. Near the southern boundary of the last-named lease a tongue of fine-grained greenstone appears to run northwards through the amphibolite, of which it is evidently an altered portion, to a point about three and a half chains west of the western corner of former G.M.L. 4490E, Colleen Bawn; thence the amphibolite runs southward east of the greenstone tongue to a point a little to the south of the Parkestown Road, specimens being obtained from two dumps between this and the Bulong Road; none, however, were found south of the latter, and apparently the northern boundary of the fine-grained greenstone runs between the two roads; it is, however, entirely obscured, and since the latter rock is regarded as an altered form of the amphibolite, the change is probably very gradual, and the position of the boundary line between the two rocks would, in any case, be largely arbitrary.

The eastern boundary of this belt probably runs about eight chains west of H.L. 176E, near the north-east corner of the map; thence it runs south to cross the Kanowna Road about three chains east of the east corner of M.H.L. 202E and pass through the old "Phœnix" brick pits, where the junction of these rocks with the probable sedimentary beds can be seen; unfortunately, both rocks are completely weathered.

Except in the Transcontinental Railway cutting, where both rocks are highly weathered, the junction between the fine-grained amphibolites and the Younger Greenstones is nowhere visible, and the relationship between them cannot be determined in the field.

On dumps in the former Monte Carlo and Queen of the West leases, where the freshest forms of the fine-grained amphibolites occur, derivatives of the quartz-dolerites are also found, and, were these shafts accessible, some light might be thrown on the relationship between these rocks.

The fine-grained amphibolites are found to vary with different localities, but may be grouped into two main types:—The first is a very fine-grained, dense, hard, massive, greenish-grey rock showing in section small lath-shaped felspar forms, now largely saussuritised, in a confused fibrous mass of pale hornblende; minute grains of zoisite occur all over the slide. The Queen of the West rock [**11033**] has a distinctly doleritic appearance in section, and has probably been derived from a fine-grained basaltic dolerite.* The Monte Carlo [**2950**] and Red Hill Extended rocks are of very similar appearance both in the hand specimen and in section.

The second type is similar in colour to, but coarser in grain than the first type, and long needles of actinolitic hornblende can be seen by the naked eye; both in the hand specimen and in section it closely resembles the actinolite-zoisite amphibolites derived from some of the doleritic members of the Younger Greenstones, while some of the coarser varieties are, at first sight, not unlike some of the quartz-dolerite amphibolites in the hand specimen. The lath-shaped felspars characteristic of the first type are absent from this type, in which the confused structure is more apparent, and which is seen in section to consist of long thin needles of actinolitic hornblende in a fine-grained mass of epidote and zoisite. This type is commoner in the eastern belt, typical specimens being found east of the former Sir John G.M.L. 4468E and on the North End Extended G.M.L. 4485E. In the western belt specimens of this type were obtained from a dump near the southern end of the golf links and about 5 chains west of the Menzies railway line. In some varieties of this type there is a development of numerous pale yellowish chloritic, apparently phenocrystal forms; specimens containing these were obtained from an outcrop and shaft about 35 chains west of the Menzies Railway line opposite M.H.L. 200E, and also in the eastern belt from a costeen 5 chains north of the west corner of G.M.L. 4037E.

Of striking appearance is a variety common to both types, in which there is a development of numerous pale spheroids of varying size, but usually about a quarter-inch in diameter, which show up strongly against the darker body of the rock. These spheroids, like the main mass of the rock, are composed of hornblende and zoisite, but with the latter present in far greater proportion. One of the best examples was found on a dump about 110 feet west of the eastern boundary of the Rising Sun G.M.L. 4039E, between the Parkestown and Bulong roads. Less well marked spheroids are also found in specimens from the dump of the previously mentioned shaft west of the Menzies Railway and M.H.L. 200E. The origin of this spheroidal structure which is also developed in some of the

*The microscopical features of these and other rock types are from determinations by Mr. R. A. Farquharson, Petrologist to the Survey.

fine-grained greenstones is not certain, but it is probably due to contact alteration, being found practically within a belt about 5 chains in width along the eastern boundary of the younger greenstones.

Only one analysis has so far been made of a fine-grained amphibolite, namely the Queen of the West rock (Table II., No. 1). The silica percentage is seen to be higher in this rock than in any member of the younger greenstones with the exception of the actinolite-zoisite amphibolites, being higher even than in the quartz-dolerite amphibolites; while the percentage of lime is somewhat lower than in those rocks. It is, however, unsafe to generalise too much on the analysis of one specimen only.

No ore deposits of any importance have been found in these rocks, and from an economic point of view they may be disregarded. It should be mentioned that on the maps the country rock of the North Collier mine, in which a rich "pipe" of ore was found associated with a body of jasper (*vide* Bul. 51, pp. 48/9), is shown as fine-grained amphibolite. There is, however, a small local development of the corresponding greenstone in the vicinity of the ore body.

(b) *The Fine-Grained Greenstones.*

By the formation of chlorite and carbonates in place of the hornblende, zoisite, epidote, etc., the fine-grained amphibolites pass into the fine-grained greenstones, various intermediate stages being found.

Both Gibson and Maclaren group these rocks and the next group together under the title of "calc-schists," but since the type rocks of each are quite distinct, although there is every gradation between them, the writer has adopted Thomson's classification into two groups corresponding to subdivisions of the Intrusive Greenstones.

These rocks occupy the more southerly portion of the eastern belt of the Older Greenstones. Owing to the greater number of mine workings in them, their western boundary, with the exception of that portion immediately south of Williamstown, can be mapped with a greater degree of certainty than that of the corresponding amphibolites; its exact position in the Westralia United mine (former North End mine) is not certain, the rock on the eastern side of the lode channel being too highly altered to permit of definite determination, but from the presence of well-marked spheroids in places in the oxidised zone it probably forms the eastern wall of the southern portion of the lode, the northern portion being entirely in the previously-mentioned tongue of fine-grained greenstone. The junction between these rocks and the quartz-dolerite derivatives

has been cut in workings in the Fair Play Extended immediately north of the Bulong road, also in the former G.M.Ls. 547E, Creswick, and 4259E, Conundrum, but in each case the rocks were too highly weathered to determine the relationship between them. There appears, however, to be a development of considerable jointing and possibly faulting in the fine-grained greenstone.

These rocks vary greatly in the hand specimen, but all are fine in grain and of a greenish-grey colour, usually somewhat paler than the corresponding amphibolites; they not infrequently show white veinlets of carbonate. Though usually massive they are often schistose, particularly in the vicinity of the lodes, and show considerable jointing and sometimes brecciation, having evidently been subjected to severe dynamic action (*vide* Fig. 42 and Plate IV.) All are composed of varying proportions of carbonates and chlorite, while sericite and rutile are common, in addition to pyrite and other iron ores; there is usually a total absence of original structure. The massive rock is best seen in workings from the Creswick main shaft [**13744**]; in the Brown Hill Junction the rock is more schistose. Very interesting specimens were obtained by Mr. W. D. Campbell from the lower levels of the latter mine, now, unfortunately, inaccessible. Some of these show intense shearing and brecciation and a curious development of large white ovoid areas of calcite, up to 1½ inches in length by 1 inch in depth [**2827**]. Another very interesting specimen [**2828**] shows numerous small white spherules of carbonate in a dark greenish-grey groundmass and has the appearance of having been an amygdaloidal basalt. A spheroidal or ellipsoidal variety similar to that of the fine-grained amphibolites is common, good examples occurring in the Brown Hill Junction and on the dump of a shaft near the south-west corner of M.L. 104E. As in the amphibolites the spheroids contain the same minerals as the groundmass, *i.e.*, chiefly carbonates and chlorite, with the carbonate in greater proportion; the spheroids are frequently arranged in lenticular patches. In the schistose varieties the spheroids, or, in this case, ellipsoids, are elongated parallel to the planes of schistosity, showing that shearing has taken place subequent to their formation. The spheroidal varieties are found in a belt forming the southerly extension of the belt of the spheroidal varieties of the amphibolites, but more detailed examination shows that they occur mainly along the contact with the Fair Play Extended—Creswick—A.W.A United band of quartz-dolerite derivatives rather than at the contact with the ultrabasic rocks as stated by Thomson.*

In chemical composition the fine-grained greenstones (Table II., Nos. 2 and 3) closely resemble the fine-grained amphibolites, the main difference being, as one would expect, in the percentage of CO_2 present.

* *Loc. cit.*, p. 634.

The fine-grained greenstones and calc-schists are regarded by Dr. Maclaren as being normally barren, the occurrence of important ore-bodies therein being, he considers, due to auriferous solutions having travelled from the quartz-dolerite dyke to which these ore-bodies are in fairly close proximity. Mr. Gibson* states that "in economic importance the calc-schists probably rank next to the quartz-diabases" (the Golden Mile type of quartz-dolerite greenstone), "many auriferous deposits of considerable importance occurring within them. These, however, have, so far, always been at no great distance from the newer intrusives." Mr. Gibson does not, however, state what conclusions he draws from this fact.

Amongst the ore-bodies occurring in these rocks at the North End may be mentioned the North End Mine's main lode—partly in fine grained greenstone, partly at its contact with the Younger Greenstones; two parallel lodes in the Isabel G.M.L., the eastern ore bodies of the Creswick and those of the Brown Hill Junction and the Mt. Ferrum Consols. It will be noticed that these are all situated near the contact with the quartz-dolerite derivatives, and, moreover, all or nearly all, connect with a narrow and very persistent formation, to be described later, which runs through the Isabel, Creswick and A.W.A. United leases, and which follows the junction of the two rocks fairly closely. This evidence would seem to bear out Dr. Maclaren's views, but more will be said on this point later. Other than those already mentioned, but few lodes occur in the fine-grained greenstones, and these rocks seem to be of little economic importance except near their junction with the Younger Greenstones. Although rich patches occur, usually under special circumstances, the lodes in these rocks are generally poorer and more patchy than those in the Younger Greenstones.

(c) *The Calc-Schists.*

By the development of pyrite and additional carbonates, sericite and quartz at the expense of the chlorite, the fine-grained greenstones pass into the calc-schists.

These rocks, which, as previously mentioned, occur within this area only as local modifications of the preceding group in the vicinity of the local formations, are pale grey or greenish-grey in colour, frequently blotchy in appearance, very fine in grain, and show frequent veinlets of calcite. Though generally massive in "The Mile," in this area the schistose varieties predominate. The best specimens obtained by the writer were from the former Mt. Ferrum Consols G.M.L. 4230E, near the hanging wall of the lode [13776]. In section, they are seen to be composed chiefly of very finely granular carbonates, sericite, and some quartz, rutile is commonly present and small grains of pyrite are frequently distributed through the rock.

* *Loc. cit.*, p. 18.

2. A.—THE INTRUSIVE OR YOUNGER GREENSTONES.

The rocks of this series occur within this area as a large dyke-like mass with a general strike of rather less than 30 degrees west of north and apparently intrusive into the Older Greenstones. This dyke extends beyond the limits of the map, both to the north and to the south; northwards its full extent is unknown, southwards it extends beyond the Golden Mile. Within this area it reaches its greatest width of rather more than a mile, near the middle of the map—its full extent to the west of Mullingar being, however, hidden by superficial deposits. It narrows considerably to the north, being little more than 30 chains in width as it passes beyond the limits of the map. At the southern end of the map, the western boundary is again obscured, but the dyke seems to have narrowed to a width of about half-a-mile; it widens again as it approaches The Mile.

One other occurrence of the Younger Greenstones was observed within this area, specimens of quartz-dolerite amphibolite being obtained from a dump on M.L. 105E, north of the Bulong Road. This occurrence may represent the northern end of Dr. Maclaren's Brownhill branch, or form part of another smaller branch. It was not seen *in situ*—the shaft being inaccessible—and is, therefore, not shown on the map.

Although the western boundary of the main dyke is completely obscured, in places, at any rate, it extends considerably further west than shown on Mr. Gibson's map.* The eastern boundary, adjoining the eastern belt of Older Greenstone can be followed comparatively closely, though doubtful at some points owing to the similarity between some altered forms of the quartz-dolerites and dolerites and the fine-grained amphibolites; on the whole it, too, runs somewhat further west than shown by Gibson.

The Younger Greenstones vary from basic to ultra-basic, viz., from derivatives of quartz-dolerite or quartz-gabbro to probable peridotite derivatives. The change from one type to another appears to be gradual, and, in consequence, the positions of boundary lines between the different members of the series is, to some extent, arbitrary. From their general occurrence in the field, the different members of this series appear to have been intruded as one mass, different portions of which varied greatly in composition, rather than as a series of separate dykes, with an interval of time between each. This question will be gone into more fully on a later page. On the whole, in this portion of the field, the western half of the dyke is less basic than the eastern, although small areas of quartz-dolerite derivatives occur along its eastern margin.

* *Loc. cit.*, Plate II.

(a) *The Quartz-Dolerite Amphibolites* [*Epidiorites* (a)].

The main area of these rocks is a belt of greatly varying width, usually occupying the westernmost portion of the main dyke, but extending over its full width at the southern end of the map. splitting into two branches at the southern end of Mt. Gledden. The western branch runs northwards through the western portion of the Cassidy Hill—where it is about five chains in width—Hannan's Reward and Mt. Charlotte leases; thence through Mullingar—where it reaches its greatest width of about 25 chains—gradually narrowing, to apparently tail out to the west of the Hannans North No. 2, the quartz-dolerite greenstone spreading across to the western edge of the dyke; a deposit of laterite, however, obscures the rocks at this point. North of the former Monte Carlo lease, the quartz-dolerite amphibolite is again in evidence, being exposed on a few dumps about 20 chains north of M.H.L. 83E and beyond the limits of the map; its boundaries, however, are entirely hidden. The eastern branch runs between the eastern slope of Mt. Gledden and the western boundary of Williamstown, apparently ending before it reaches the main road leading to Bulong and Parkestown. Another small area occurs to the north along the same line, on the northern slope of Mt. Charlotte; and small areas of this rock occupy the eastern margin of the main dyke along the western boundary of the Isabel and in the western portions of the Euclid and Devon Consols South Ex. leases; while, as already mentioned, a small outcrop occurs near the corner of Harley and Hinemoa Streets, and, finally, there is the occurrence of specimens of this rock on a dump on M.H.L. 105E.

Although some varieties of particularly coarse grain show traces of a gabbroid structure in section, in by far the greater number the remains of structure shown are of an ophitic character, and the original rock was, in the main, undoubtedly a quartz-dolerite, merging into a quartz-gabbro in places.

As oxidation has seldom reached any great depth in the rocks of this group, outcrops are fairly common.

The type rock, corresponding to Thomson's "epidiorites with micropegmatite" and Gibson's "felspathic amphibolites," is exposed in outcrops at the back of the Warden's Residence, in Wordsworth Street, east of the Mullingar Quarry, on a dump on the Gem G.M.L. 4331E, and also on outcrops on the western slope of Mt. Charlotte and on the Hannans Find G.M L. 4470E. In the hand specimen these are fairly fresh, medium coarse-grained, massive, hard, fairly tough rocks, showing crystals of dark green hornblende scattered in a white, felspathic ground, giving the rock a speckled appearance; to the naked eye, the two minerals appear to be present in fairly equal proportions, varying slightly in different locali-

ties. In section these rocks are seen to consist of uralitic hornblende, columnar crystals of plagioclase felspar—usually saussuritised—with some interstitial quartz, and micropegmatite is frequently, but not always, present; apatite is common; original ilmenite is now largely replaced by leucoxene. (For analysis, *vide* Table II., No. 4.)

The rock from the eastern margin of the main dyke, as represented by specimens from the Euclid shaft [12740], is very similar to the above, but the original ferro-magnesian mineral is now largely represented by chlorite, while a fair amount of carbonate is present in addition to saussurite, and there is much leucoxene, the rock generally showing an intermediate stage between the amphibolites and the greenstones. Fair-sized areas of granular epidote were present in fragments of quartz on the dump.

A very coarse pegmatitic variety of the quartz-dolerite amphibolite is found on a dump near the centre of the former Eaglehawk United G.M.L. 3770E, at the foot of the western slope of Mt. Gledden. Specimens from the dump [12937] show a dark green rock with large platy crystals of hornblende, usually about half an inch in length. Thomson's* mentions one measuring four cms. in length by one cm. in breadth and two mm. in thickness; though usually flat, the hornblende plates are frequently curved to resemble the section of a barrel. In section the rock resembles the more normal amphibolites, but a good deal of chlorite and carbonates are present and the structure is less markedly ophitic. The rock is associated on the dump with more numerous fragments of a rock [12938], resembling those of the normal type, but finer in grain, and with the ferro-magnesian present in greater proportion. Both varieties are frequently found in the one specimen.

The coarser gabbroid variety occurs in various localities, notably on a dump on the northern slope of Mt. Charlotte [13814], also on a dump about half way along the road from Williamstown to the corresponding station on the Brown Hill Railway line, and east of G.M.L. 4470E [12935]. A specimen [13419] with gabbroid affinities was also obtained from the dump of the Hannans Hill water shaft. These rocks are not greatly dissimilar to the Warden's residence type, but the ferro-magnesian is present in greater proportion, and in section large interstitial quartz plates and exceptionally large rods of apatite are seen, and the structure approaches the gabbroid.

But few lode formations occur in the quartz-dolerite amphibolites, and these are extremely low in grade. Such occur on former G.M.L. 4470E, Hannan's Find, and on G.M.L. 4524E, on the north-east slope of the Mullingar Hill. Some cross veins of quartz

*Loc. cit., p. 646.

extend from the greenstones into these amphibolites, but they are seldom payable below the limit of the oxidised zone, which in these rocks is usually not far from the surface. In the Kalgoorlie district, therefore, these rocks are practically of no economic importance, although in other districts where the ore-bodies occur as reefs rather than lode-formations payable deposits are found therein.

(b) *The Quartz-Dolerite Greenstones.*

The passage of the quartz-dolerite amphibolites into the corresponding greenstones can be traced through intermediate varieties.

The main belt of these rocks starts at the southern end of Mt. Gledden and runs northwards through Cassidy Hill, Hannan's Hill and Mt. Charlotte; thence across the Kanowna Railway line and through the Napoleon, Golden Zone and Ineeda leases, apparently tailing out in the vicinity of the old Monte Carlo.

Another small belt starts near the southern end of Williamstown and runs north past the south-west corner of the Isabel to join the small area of quartz-dolerite amphibolite east of the Fair Play. A third area of these rocks is found crossing Hinemoa Street, west of Mullingar, but its northerly and southerly extensions could not be traced.

In this area these are usually dull greenish grey rocks from medium to fairly fine in grain, being usually somewhat finer-grained than the preceding group, from which, owing to their indefinite appearance in the hand specimen they are easily distinguished. Though usually massive, schistose varieties occur. Small, pale purplish patches of leucoxene are frequently distinguishable in the hand specimen, and in the coarser varieties outlines of former felspars are sometimes visible. In section they are seen to consist largely of granular carbonate, together with chlorite, much quartz, and a pronounced development of leucoxene and micropegmatite. Varieties in which there is a large development of tourmaline are found in the Mt. Charlotte G.M.L. 211E [**13472** and **13468**].

The chemical composition of specimens of these rocks is shown in Table I., Nos. 5, 6 and 7. In the eastern belt of these greenstones there is sometimes a tendency towards the gabbroid structure ([**13740**] A.W.A. United), found in some of the amphibolites.

Economically this group is the most important of any. On The Mile it, together with the bleached varieties, forms the country rock of most of the rich lodes. At the North end, lode formations are not so common in these rocks, the Golden Zone line of lode being the most persistent. Of considerable importance, however, are two series of quartz veins striking across the country, the one at

about 30 degrees north of east and varying in dip from 60 degrees to the north to verticality; the other striking nearly east and west and dipping to the north at about 30 degrees. Both series carry good values, there being little to choose between them in this respect. Such veins have been worked to a very great extent in the Hannan's Reward-Mt. Charlotte mine and also in the Cassidy Hill, Cassidy's North, Maritana and Cunard mines.

(c) *The Bleached Greenstones.*

Between the type rocks of this and the previous group there is every gradation, and the relationship between the two is obvious

Fig. 1.

when the rocks are seen together *in situ*. Typically, these are whitish to pale grey or pinkish rocks, usually of medium grain and

somewhat granitic appearance, but characterised by the presence of pyrites, often in large quantities. Although attaining a large development on The Mile, at the North End they are usually found as narrow bands a few inches in width on the walls of the cross quartz veins (*vide* Figs. 1 and 11). They differ from the rocks of the preceding group in the complete or almost complete absence of chlorite with the development of pyrite, which is sometimes found replacing leucoxene and greater quantities of quartz, sericite, and carbonates, and have evidently resulted from the action of sulphur-bearing solutions, and represent a greater degree of vein alteration than the preceding rock. Typical specimens are found on the Hannans Reward-Mt. Charlotte leases [2765, 2775], and also occur in a crosscut from the northernmost shaft in the A.W.A. United G.M.L. 4051E [12924]. Schistose varieties of these rocks are found in the east crosscut at the 290ft. level from the "Charlotte" Main Shaft [13464].

(d) *The Actinolite-Zoisite Amphibolites.*

The original forms of the rocks of this group would be extremely doubtful, were one to judge by the individual specimens alone. In general appearance, composition and usual absence of igneous structure, they closely resemble the second type of fine-grained amphibolites, with which one would be tempted to group the majority, were it not for the opposing field evidence. They can be separated into two subdivisions:—

(a) Those derived from quartz-dolerites, and

(b) Those derived from dolerites.

(a) The relationship of the rocks of the first subdivision can be more easily traced than those of the second. The only occurrence observed was a small outcrop in Hinemoa Street, between the previously mentioned areas of quartz-dolerite amphibolite and quartz-dolerite greenstone in that locality; the gradual passage of the actinolite-zoisite rock into the quartz-dolerite amphibolite could easily be traced in the field.

These rocks are fairly coarse in grain and of a somewhat mottled appearance. In the hand specimen, the long blades of greenish-grey hornblende can readily be traced by their lustre. In some sections these rocks are very similar to the normal quartz-dolerite amphibolites, except for the development of actinolitic hornblende, and remnants of an ophitic structure can be seen. Other sections sometimes from the same specimens as the last, present a more altered appearance, the felspars being represented by a mass of epidote and zoisite grains, whilst the structure is indefinite.

(b) The rocks of the second subdivision more closely resemble the fine-grained amphibolites in outward appearance. They are fairly hard, tough, dark greenish-grey rocks, fairly fine in grain, but the needles of actinolitic hornblende, though smaller than in the rocks of the first subdivision, are easily discernible. The outcrops of these rocks sometimes show spheroidal weathering. They are found in a roughly oval-shaped area extending southwards from the southern end of the Bonnie Play G.M.L. 4088E, through the western portion of the Fair Play G.M.L. 4052E and the north-eastern half of the Hidden Secret North G.M.L. 4035E. Some of the rocks now grouped as dolerite greenstones have evidently been derived from rocks of this type, as intermediate forms composed of actinolitic needles, party chloritised, in a ground-mass of carbonates and sericite, are found on G.M.L. 4035E and at the 400ft. level from the Hidden Secret main shaft.

The fact that the gradual passage of these rocks into the platy hornblendites (Bonnie Play G.M.L. 4088E, crosscut from a shaft 170 feet north-west of the east corner) and into the talc-chlorite-carbonate rocks derived therefrom (east crosscut from shaft on former G.M.L. 4080E, north-east of G.M.L. 4035E) can be traced in the field is strong evidence in favour of their inclusion in the Younger Greenstone series. An analysis of one of these rocks (Table II., No. 7), however, agrees very closely with those of the Older Greenstones. These are probably the rocks described by Thomson* as a thin band of fine-grained amphibolite separating the large "intrusion" of ultrabasic rocks from the main quartz dolerite dyke. Small and apparently unpayable lode-formations occur in these varieties of amphibolites, which, from an economic standpoint, may be disregarded.

(e) *The Dolerite Greenstones.*

Other than subdivision (b) of the actinolite-zoisite amphibolites, no dolerite-amphibolites were found within this portion of the field. Dr. Thomson, however, mentions† their occurrence as a local facies of the quartz-dolerite amphibolite at Kalgoorlie, the locality not being given; and he further states that they "are more abundant in the ridges to the west of the town."

On the other hand, dolerite greenstones, which are not mentioned by the last-named writer, occupy a fairly large area. The main belt of these rocks starts near the southern end of Williamstown and includes most of the area covered by the township, the western portion of the Hidden Secret group of leases, the Hannans Reward North, the Red White and Blue, part of the Sons of Gwalia, practically the whole of the Devon Consols, and probably the eastern portion

* *Loc. cit.*, p. 623. † *Loc. cit.*, p. 642.

of the Union Club G.M.L., ending probably in the vicinity of the boss of albite-porphyrite east of the Ivy. The belt of this rock in which the Mullingar quarry is situated has already been mentioned —its northern and southern extensions are obscured. Another small area is found east of the junction of the Bulong and Parkestown Roads, being exposed in a small quarry near the centre of the Bonnie Play lease; at its southern extremity this branch joins the area of actinolite-zoisite amphibolite. Another branch, probably joining the last in the Rising Sun G.M.L. 4039E, is found on the Fair Play, where it can be seen both in the mine workings and in a fairly prominent outcrop 200 feet south-west of the main shaft. Small patches of these rocks, not mapped, occur within the area shown as talc-chlorite-carbonate rock, with which they are so closely associated—there being apparent intermediate forms—as to suggest that they are variations of the same rock-mass.

Gibson makes no mention of these rocks under this title, but a portion of the area occupied by them was mapped by him as a "basic" variety of the "coarse-grained amphibolites";* the rock in the small quarry in the Bonnie Play he classes as a derivative of peridotite, but states† that it is rather on account of its agreeing very closely in analysis (Table II., No. 8) with the carbonated peridotite occurring on the western edge of Hannan's Lake than on its petrological characters. In section this quarry rock [**11029** and **12738**], as examined by Mr. Farquharson, is found to consist of fibrous platy chlorite, a fair amount of carbonate in shapeless plates, and also of irregular platy felspars largely kaolinised; a little quartz is present and also some rutile needles—these features hardly agree with those of an altered peridotite, and the analysis of so highly altered a rock can hardly be a guide, as there is frequently a migration of a portion of the original rock constituents; in the case of these rocks, as with the quartz-dolerite greenstones, the formation of the numerous cross veins of quartz would lower the silica percentage, whilst the introduction of CO_2 in large quantities would reduce the percentage of the other constituents; moreover, the relative proportion of MgO to CaO is less than that shown in the analysis of a platy hornblendite (Table II., No. 10); it must be admitted, however, that the percentage of alumina is somewhat low.

In general these rocks are composed of carbonates in large quantities, chlorite, felspars now chloritised or kaolinised; leucoxene and pyrite are frequently present, and in some specimens the presence of a little interstitial quartz links these rocks with the quartz-dolerite greenstones; micropegmatite is absent. Traces of an ophitic structure are occasionally found.

* *Loc. cit.*, Plate I. † *Loc. cit.*, p. 46.

Other than some of the fuchsite-carbonate-quartz rocks described later, the writer did not notice any bleached varieties of these rocks, although such may occur.

Economically the dolerite greenstones are of considerable importance, forming as they do the country rock of the Hidden Secret and Fair Play lodes, while numerous cross quartz veins have been worked on the Bonnie Play and Red White and Blue leases.

(f) *The Lustre-mottled Amphibolites.*

Rocks of this type are not found strictly within the limits of the map, but an outcrop occurs about 13 chains south of west from the Rifle Range hill, probably only a local variation from the quartz-dolerite amphibolite.

In the hand specimen these are massive, coarse-grained, dark greenish rocks, with large irregular hornblende crystals showing the characteristic lustre-mottling. A specimen from the above-mentioned outcrop proved in section to consist of nearly colourless to bluish-green hornblende, felspar largely epidotised and zoisitised, and irregular pieces of leucoxene; an ophitic structure was apparent. No analysis was made of this specimen, but for comparison with other types, that of a specimen [**2117**], somewhat carbonated, from the Great Boulder No. 2 main shaft, has been inserted (Table II., No. 9). A detailed description of these rocks is given in Dr. Thomson's paper.*

The lustre-mottled amphibolites are of no economic importance.

(g) *The Platy Hornblendites.*

Fairly fresh rocks of this type occupy an area which includes the south-western portion of the North End Extended G.M.L. 4485E and the greater portions of G.M.Ls. 4368E Dar Kan, and 4507E North End Deeps. Another small area, roughly on the same strike, but separated by the Bonnie Play branch of dolerite greenstone, is found at the junction of the Bonnie Play, Fair Play, and Fair Play Extended leases.

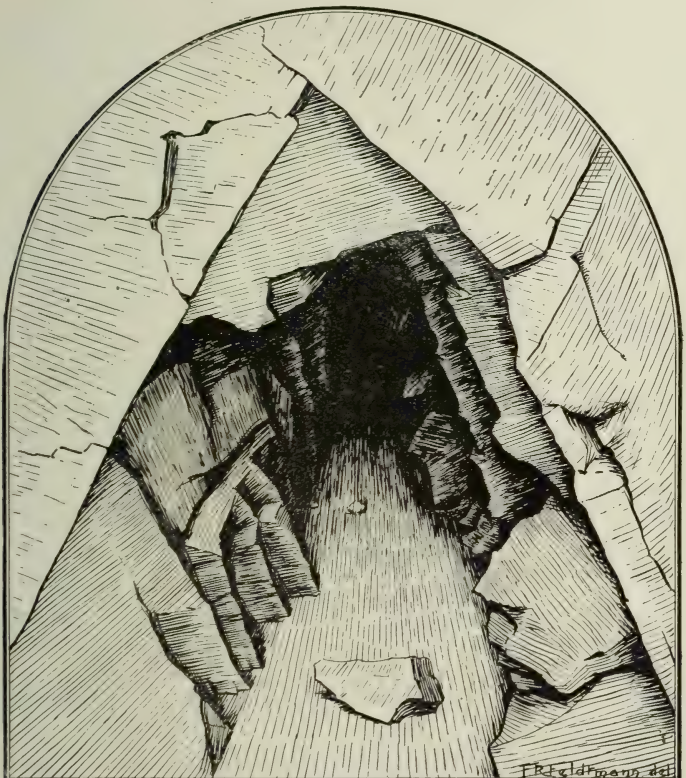
The hornblendites are tough, massive, dark greenish rocks, of medium coarse grain, wholly, or almost wholly, composed of aggregates of platy hornblende crystals of uniform grain [**12739**]; a marked sharply angular jointing is characteristic of these rocks (Fig. 2). In section the hornblende appears as large platy pale greenish crystals and also as extremely fibrous forms in a base of chlorite, carbonates, sphene, and fibrous hornblende. For an analysis of a specimen from a shaft near the western end of the boundary between the North End Extended and the Dar Kan leases, *vide* Table II., No. 10.

**Loc. cit.*, p. 639, *et seq.*

On Mr. Gibson's map* these rocks are included in the "basic amphibolites."

By the development of talc, chlorite, and carbonates the hornblendites pass through intermediate forms into the next group. They are of no economic importance.

Fig. 2.



BONNIE PLAY G M L 4088E Eastern Shaft
Sketch showing sharply angular jointing of hornblendite

(h) *The Talc-Chlorite-Carbonate Rocks.*

These rocks are found over a wide area, reaching their greatest development in the more northerly portion of the area mapped. North of the Kanowna Railway line they appear to occupy the eastern half of the Younger Greenstone dyke. No unweathered out-

* *Loc. cit.*, Plate I.

crops are found, the rock being exposed only on dumps and in mine workings, but these are sufficiently numerous to enable a fair estimate to be formed of the extent of these rocks; their boundaries are entirely obscured. The northerly continuation of the main belt of these rocks beyond the limits of the map can be traced by a dump about three chains west of the western corner of the former Rifle Range Reserve 8353. South of the Kanowna Railway a smaller band starts near the laterite-capped hill south of the Devon Consols, and runs south to the southern end of the Bonnie Play. Another area occurs between the Fair Play and Hidden Secret mines; in places this last area is less altered than usual and shows intermediate forms approaching the hornblendites.

These rocks are usually massive, but sometimes schistose. In the hand specimen they are medium fine to fine in grain, either pale greenish-grey or dark grey in colour, can be scratched by the finger nail, and are usually very soapy in feel, though sometimes rather gritty owing to the number of small carbonate crystals frequently visible to the naked eye. In section they are usually found to consist of much carbonate, aggregates of chlorite and also of talc and a little quartz; rutile is common. Carbonate veins in these rocks prove to be composed of a ferriferous variety of dolomite, and the carbonate in the rocks themselves is probably largely of this character. Analyses of these rocks (Table II., No. 11) approximate to those of the hornblendites, the chief differences being the lower percentage of silica and the marked increase of potash.

In Mr. Gibson's map of the North End, the area occupied by these rocks is shown as "Quartzose Amphibolite," but on the 30-chain map he also shows two peridotite dykes, evidently regarding the talc rocks as derivatives of the latter. Owing to the comparative absence of mine workings at the time of his survey, he failed to note the full extent of the area occupied by these rocks.

The talc-chlorite-carbonate rocks have not, on the whole, proved of great economic importance, but low grade formations, such as the Mystery line of lode, have been worked therein. This formation occurs at the contact with the large albite-porphyrite dyke occupying the centre of the 10-chain map. 'Smith's lode,"* also in the talc-rocks is, so far as can be judged from the oxidised rock, a line of fuchsite-carbonate-quartz rock in which there are numerous cross quartz veins, in which the gold usually occurs. Other low grade formations such as those of the former Sir John and the Union Club leases appear to be associated with albite-porphyrite dykes, but in these instances the rocks are too decomposed for definite determination.

* Bulletin 51, pp. 41-42.

(i) *The Talc-Mesitite Rocks.*

Only one small area of these rocks occurs within the limits of the map, namely, to the east of G.M.Ls. 4529E, 211E, and 97E, and in the South-Western portion of G.M.L. 796E. Its boundaries were nowhere visible, and those shown on the map do not pretend to any degree of accuracy. This area lies to the east of a belt of fuchsite-carbonate-quartz rock, with which it is evidently closely associated.

In the hand specimen these rocks resemble those of the preceding group, except for the marked development of very coarse mesitite ($2MgCO_3$ $FeCO_3$) crystals, sometimes reaching one-third of an inch in length [**13424-5**]. In addition to the coarse mesitite crystals they are largely composed of granular carbonates, some chlorite, large areas of talc, some quartz and occasionally felspar. The derivation of these rocks from an original peridotite is by no means certain. In chemical composition (Table II., No. 12) they differ from the preceding group chiefly in the very much higher ratio of the magnesia and ferrous oxide to the lime, while the alumina percentage is much lower. These rocks, together with the serpentines, represent the ultrabasic pole of the Younger Greenstone of the North End. No ore bodies have been found in the small area occupied by these rocks.

(j) *The Serpentines.*

Rocks of this character within this area are represented only by a specimen [**3391**] collected by Mr. E. S. Simpson from the dump of the old Kapai main shaft (now in G.M.L. 4320E, Ivy), and some fragments of a bore core from the 300ft. level of the same shaft. This bore was put in west from the west crosscut at this level for a total distance of 459 feet; the specimen examined is from a point 300 feet west of the crosscut. The lower levels of this shaft, from which several other interesting specimens have been obtained, were unfortunately inaccessible during my examination of the more northerly portion of the area, and although at a more recent visit I was able to get down to the 300ft. level, such portions thereof as were accessible were too much hidden by mud for much to be visible; moreover, the workings at this level appeared to be only in the jasper and the highly sheared and altered rock in the immediate vicinity. None of the serpentine rocks being found in the field, no defined area can be assigned to them on the map.

In the hand specimen these are fine-grained, soft, soapy greenish-grey rocks of fairly typical serpentinous appearance; a few carbonate crystals are visible to the naked eye. They are composed largely of aggregates of talc, with some serpentine, granular carbonates, and numerous magnetite grains. As compared with the previous group, the silica percentage (Table II., No. 13) is higher,

that of CO_2 lower, showing that carbonation has taken place to a lesser degree; the alumina is slightly higher and the ratio of magnesia and ferrous iron oxide to lime is half as great again.

Serpentines are of frequent occurrence in the eastern goldfields and are usually found closely associated with dolerites or gabbros or their derivatives. They have not so far proved of any great economic importance so far as gold-mining is concerned.

(k) *The Fuchsite-Carbonate-Quartz Rocks.*

Comparatively narrow bands of these rocks are of fairly common occurrence at the North End. They attain a width of 100 feet in places. The most persistent line runs northwards from the Hidden Secret—where it runs to the east of the main lode at the surface, but junctions with it at the 400ft. level (*vide* Fig. 15)—west of the Bonnie Play, through the Sons of Gwalia G.M.L. 3771E and the Devon Consols as far north as the Transcontinental Railway line; north of this it has not been traced. At its northern end this band is less well defined, and, owing to the absence of accessible deep workings in the two last-named mines, its exact boundaries were not determinable. A second band occurs on G.M.Ls. 211E and 97E to the west of the talc-mesitite rock; it can be best seen in the east crosscut at the 290ft. level of the "Charlotte" shaft on the former lease (*vide* Plate III.), where it is associated with bands of graphitic schist and an albite-porphyrite dyke. So far as can be judged from the oxidised rock, "Smith's lode," west of the Mystery lode, is another belt of this rock, while specimens [12257] were also obtained from the dump of a deep shaft near the centre of the Hyman G.M.L. 4406E. This last appears to be associated with the Mystery lode and is close to the northern portion of the large dyke of albite-porphyrite previously mentioned as occupying the centre of the map. Other smaller areas occur frequently associated with the lode-formations and usually in the vicinity of dykes of albite-porphyrite.

Numerous cross veins of milky quartz, usually auriferous, and resembling those of the greenstones are characteristic of these rocks (Fig. 3), the fuchsite scales being thickly congregated round the veins round which are also coarse and fine crystals of pyrite in fair quantities. Typical specimens are hard, medium fine to fine-grained, granular rocks, usually massive but frequently sheared and schistose and of a pale emerald green colour due to the fuchsite; veinlets of carbonate or cryptocrystalline quartz are numerous in them.

Analyses (Table I., No. 1. and Table II., No. 14) of two specimens agree fairly closely, both with each other and with that of the talc-mesitite rock, except that in the one from the Hyman the per-

centage of lime is very low, most of it having probably been removed from the body of the rock to be deposited in veins which were not included in the piece analysed; veinlets of carbonates in specimens from the Hyman and Hidden Secret show considerable effervescence with HCl, thus confirming this view. The CO_2 in the

Fig. 3.

Sketch showing Southerly dipping cross quartz vein Q in fuchsite-carbonate-quartz rock Mgf, faulted by series of fault planes §. Hanging wall shear plane HW. & dolerite greenstone Ac_1.

fuchsite rocks is nearly double that of the talc-mesitite rock, and the percentage of the other constituents is consequently lower; the combined water is lower, and much potash has evidently been introduced; the chromium percentage is almost identical. In the specimen from G.M.L. 211E the ratio of lime to magnesia and ferrous oxide is midway between that of the talc-chlorite-carbonate and talc-mesitite rocks. In general the analysis of [10913] agrees very closely with that of a similar rock from the Ingliston Extended G.M. at Meekatharra.* It should be mentioned that of the two North End specimens, that from the Hyman was associated with talc-

* G.S.W.A., Bulletin No. 43, p. 80.

chlorite-carbonate rocks, that from the Charlotte mine with talc-mesitite rock.

These rocks have been regarded by previous writers as highly altered peridotites, from their composition in general, and particularly the amount of chromium present; this is most probably the case in some instances, but close examination of the North End rocks in the field shows that they pass insensibly into the surrounding country, which may be dolerite-greenstone, talc-chlorite-carbonate, or talc-mesitite rocks; the inference being that they are the results of vein alteration of various rocks, certainly strongly basic in composition, and usually ultrabasic, but are not necessarily the highly altered forms of any one rock. That a high percentage of chromium does not necessarily prove the peridotitic origin of a rock is shown by the analysis of a hornblendite.

The close association of these fuchsitic rocks with dykes of albite-porphyrite is most noticeable and suggests that the solutions which attacked the original rocks were in some way connected with the intrusion of the albite-porphyrite.

It should be stated that except in the case of vein-altered specimens, no potash is present in those albite-porphyrites which have been analysed, but on the other hand the hornblende-porphyrites show a fairly high percentage, and if, as seems probable, these two rocks are closely connected, the potash may well have been introduced by later emanations from the porphyrite magma. The occasional presence of tourmaline in the fuchsite rocks tends to confirm this.

On the available evidence, then, it would seem most likely that these rocks in the North End, at any rate, are highly altered forms of the more highly basic members of the Younger Greenstones, and probably correspond to the bleached greenstones resulting from a similar alteration of the quartz-dolerites.

B.—Intermediate to Acid Intrusives.

(a) *The Hornblende-Quartz Porphyrites.*

A wide band of these rocks, largely obscured by superficial deposits, occupies the low-lying ground to the west of the town of Kalgoorlie, but only a small portion comes within the limits of the 10-chain map, of which it occupies the south-west corner. The only evidence of the occurrence of similar rocks in the main portion of the North End is that afforded by a somewhat sheared and carbonated specimen [2937] obtained by Mr. W. D. Campbell from a deep shaft 100 feet north of the west corner of G.M.L. 445Se, Hyman North, where it is evidently intrusive into the quartz-dolerite greenstone; this specimen was described in detail by Mr. Farquharson on p. 66 of Bulletin 51.

These rocks vary considerably in appearance and composition, but typical hand specimens show a dark greenish or brownish grey ground, with numerous white felspar phenocrysts and occasional small blebs of quartz; hornblende phenocrysts are fairly common in section, but are seldom visible in the hand specimen. (For analysis *vide* Table II., No. 15.)

Similar rocks are well developed at Bulong, where outcrops are common. In that locality, specimens from the one dyke show marked variation, some closely resembling the next group of rocks, pointing to a possible connection between the two. Unfortunately, specimens collected by the writer from that district have not yet been examined in detail.

Payable ore deposits have not yet been found in these rocks at Kalgoorlie—though such occur in similar rocks at Ora Banda—but it is probable that the gold-bearing solutions were closely connected with the parent magma, from which these rocks and the albite porphyrites were derived.

(b) *The Albite-Porphyrites.*

These rocks are of commoner occurrence at the North End than was previously suspected. Outcrops are infrequent and close examination is necessary to distinguish the weathered rock from highly decomposed forms of the Greenstones.

They are undoubted dyke rocks, and are usually found intruding the Younger Greenstones.

The largest dyke is that already mentioned as occupying the centre of the map, and described in Bulletin 51 as running through the Hyman, Mystery, and Lone Hand leases; it widens greatly to the south to a maximum of about nine chains near the Transcontinental Railway, where it is exposed at the western end of the cutting; before leaving the Milanese G.M.L. 4293E it appears to split, one branch running through G.M.L. 213E—the extent of this branch is not certain—the other through the Red White and Blue G.M.L. 1228E, Raven's lode occurring on the east side of the dyke, apparently a southerly continuation of the Mystery line of lode further north. Another large body of this rock, roughly oval in outline, is found to the east of the "Kapai" main shaft on the Ivy lease; specimens of this rock containing green, angular inclusions were obtained by Mr. W. D. Campbell from the lower levels of the shaft. Apparently other dykes, too decomposed to be determined with certainty, occur on the former Sir John lease to the north. Another series runs between the Mt. Charlotte-Reward Mine and Williamstown, associated with a number of jaspers, turning into graphitic schists at depth; the largest dyke of this series is found forming the western half of a small hill at the southern end of Williamstown. The

northern members of this series are closely connected with the fuchsite rock exposed in the eastern crosscuts from the "Charlotte" main shaft, where the albite-porphyrite, somewhat sheared and carbonated in places, is also visible. Other dykes, too small to be shown on the map, occur in the Fair Play Extended and Bonnie Play leases, and further mining will probably disclose others.

The albite-porphyrites are fine-grained, hard, gritty rocks of a very pale, almost whitish grey colour, the more weathered rocks showing a reddish or pinkish tinge; they show a characteristic blocky jointing in the mass, and not infrequently contain small, angular, green, chloritic and sometimes chromiferous inclusions. Both phenocrystal and non-phenocrystal varieties of these rocks occur, the former being more common; both phenocrysts and groundmass are chiefly albite felspar; a little quartz is sometimes present in the groundmass. A specimen from the Mystery shows fairly numerous hornblende phenocrysts, visible to the naked eye, and resembles some of the Bulong hornblende-porphyrites. Rutile is frequently present and tourmaline is not uncommon, particularly between the planes of sheared varieties. Sericitised and carbonated forms are common.

An analysis of a fairly fresh albite-porphyrite (Table II., No. 16) agrees fairly closely with that of the hornblende-porphyrite, the chief difference being in the large amount of potash and lime present in the latter. In more altered forms of the former rocks, a fair amount of potash is present, evidently as sericite, and the percentage of soda is less.

So far as can be judged from the somewhat weathered examples in this area, ore bodies are sometimes found in these rocks, but more commonly occur at their junction with the Greenstones.

3.—THE SEDIMENTS.

But few exposures of probable sedimentary rocks are found within this area, and these occur only at the extreme north-east cornor of the 10-chain map. They are best shown at the old "Phœnix" brick pits, north of the Transcontinental Railway line, where a width of about 80 feet of these rocks—across their strike—in addition to their junction apparently with the fine-grained amphibolites, is exposed; unfortunately, the latter rock is too weathered to permit of definite determination.

These apparent sedimentary rocks occur as fine-grained, greyish and reddish, fairly soft, sandy beds, striking about 24 degrees west of north; the usual dip is to the west at about 75 deg., but near their junction with the amphibolites, they are contorted

and faulted (Plate II., and Fig. 4.) These beds closely resemble the laminated slaty jaspers, as they appear in the oxidised zone,

Fig. 4.

Photo: F. R. Feldtmann. Neg. F202.

Southern end of Phœnix Brick Pit, showing bedding of sedimentary rocks.

but are softer on the whole, although soft kaolinic and sericitic varieties of the jaspers occur in the North Collier and its immediate

vicinity. It should be mentioned that the jaspers sometimes attain a width of 50 feet. Similar beds to those of the Phœnix brick pits are found in Walsh's quarry, in the flat west of Kalgoorlie, and beyond the limits of the map; these were regarded by Mr. Gibson* as sheared and weathered forms of the porphyrite. I do not consider that there is sufficient evidence for this assumption with regard to the Walsh's quarry rocks, although I am inclined to agree with Mr. Gibson regarding the rocks of White Cliff Quarry, about three miles south of Boulder; the rocks of the latter quarry are, however, somewhat different in appearance and do not show the bedding of the Phœnix brick pits and Walsh's quarry rocks. On the whole, I am inclined to the view that the Phœnix brick pit rocks are of sedimentary origin, although the evidence in favour of this is by no means conclusive.

So far, the sedimentary rocks have not proved of any economic importance.

4.—THE SUPERFICIAL DEPOSITS.

(a) *The Laterites.*

Lateritic deposits have been described so frequently in other reports, that no general description need be given here. Those examples found within the area under discussion are of the highly ferruginous variety, being mainly composed of hydrated iron oxide with some bauxite. Beneath the lateritic cap is a bleached kaolinic rock with occasional veinlets and patches of ferruginous matter and resulting from the removal of most of the iron from the original rock. For convenience, the term "Infralaterite" is proposed for this bleached rock. This infralaterite is often regarded by prospectors as an alluvial deposit, which at first sight it somewhat resembles, the laterite being regarded by them as the result of thermal action; both, however, result from the decomposition of the parent rock *in situ*. In the vicinity of lode formations or auriferous quartz veins, the infralaterite is sometimes found to carry gold in payable quantities, the metal having been dissolved by surface waters out of the lodes or veins, to be later precipitated as these waters percolated through the decomposed country rock. Mt. Ferrum is a good illustration (Fig. 5) of this.

Within this area laterites are most commonly found on hills within the area occupied by the talc-chlorite-carbonate rocks, also at the junctions of two or more Greenstone rocks; they are fairly common on the fine-grained greenstones and amphibolites, but are not found on the quartz-dolerite greenstones, except at

* *Loc. cit.*, pp. 40-41.

their junction with other rocks. Only one occurrence was noted in the quartz-dolerite amphibolite—on the former Hannan's Find G.M.L. 4470E.

Fig. 5.

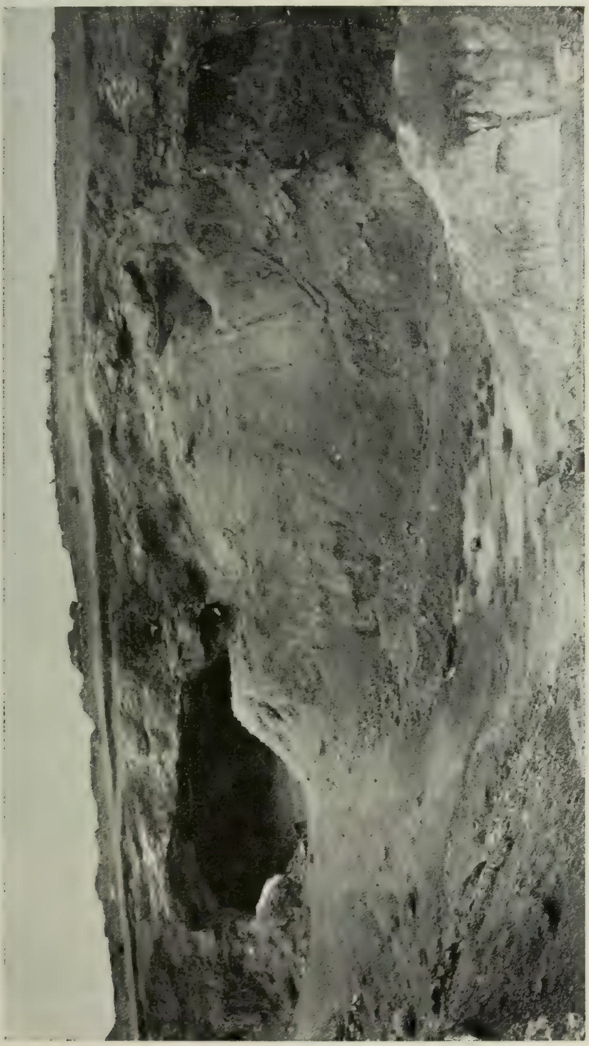


Photo: F. R. Feldtmann. Neg. F200.

Mt. Ferrum from the North, showing workings under laterite.

(b) *Sand, Loam, etc.*

In this group of superficial deposits may be briefly mentioned the gravel—including the ironstone gravel resulting from the weathering of the laterites—sand, loam, clay covering the lower

lying ground and resulting from the action of wind, rain, and changes of temperature on the exposed rock surfaces. In addition, mention should be made of the "cement" or travertine so well known on these goldfields, and resulting from the action of surface waters which have dissolved the carbonates of the greenstone rocks to re-deposit them at the surface. It may be mentioned that in districts where amphibolites only occur, this cement is apparently not formed.

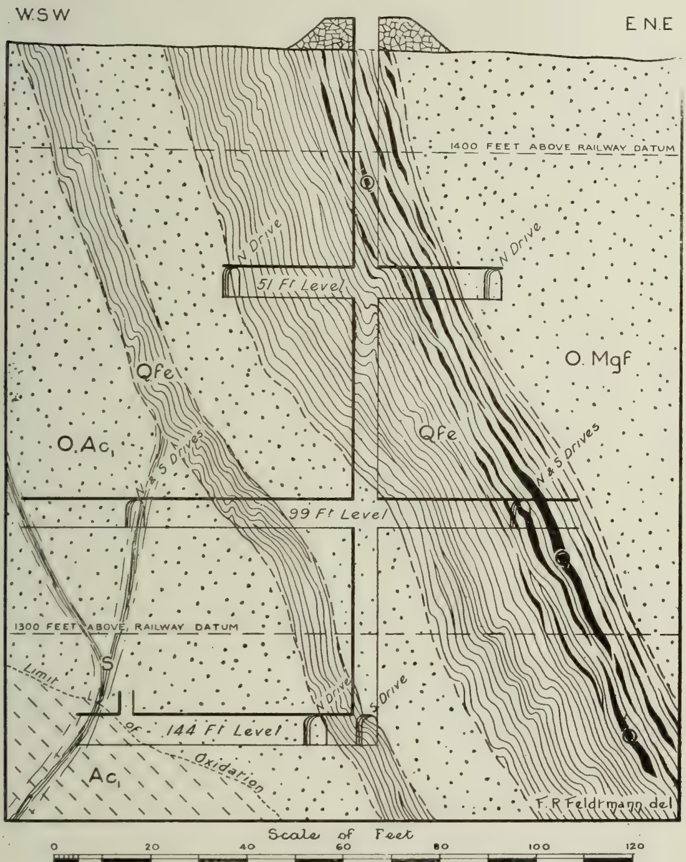
5.—Jaspers and Graphitic Schists.

Jaspers and graphitic schists are of common occurrence at the North End, the former usually passing into the latter below the zone of oxidation. These rocks are usually of extreme length as compared with their width, the most persistent within this area having been traced from a point south of the junction of the Bulong and Parkestown roads, northwards through the Lucknow, Sons of Gwalia, Devon Consols, Union Club, Ivy and Sir John leases, thence across the Broadarrow road, near the north corner of the last-named lease; and in a general northwesterly direction beyond the limits of the 10-chain map, a total distance of nearly two miles. The irregular strike of this jasper is shown on the maps, and the sections show it to be equally irregular in dip; it attains its greatest width of, approximately, 50 feet along the western boundary of the Lucknow G.M.L. 4464E, where it can be seen in the mine workings (Fig. 6). In the oxidised zone, it is mainly composed of numerous thin fine-grained slaty laminæ of pale grey or brownish grey cryptocrystalline quartz [**12947**], in which a number of small tourmaline needles were observed in section. In places these slaty laminae are highly contorted (Fig. 7), and much resemble folded sedimentary rocks. In the eastern half of the jasper, coarse lenses of usually brown and more ferruginous compact, flinty quartz, sometimes two feet in thickness, and separated from each other by slaty laminae, are common (Fig. 8). At the limit of the oxidised zone, the jasper becomes highly pyritic in places and gradually passes into a black, laminated, highly graphitic rock, with veins and nodules, either circular or elliptical in outline, of pyrite, and consisting chiefly of quartz, sericite and innumerable fine particles of carbon. Much of the gold from the Devon Consols Mine was obtained close to the western wall of this jasper, rich patches occurring at its junction with coarse, flat cross quartz veins.

Other very similar but much shorter bands of jasper occur, for example, one running south from the Hannans Reward North lease to the Lady Elizabeth, where it is exposed in workings from the old main shaft; it forms a prominent little hill between the two leases (Fig. 9—photo).

Another series of short, thick lenses, striking nearly N.E.-S.W., outcrops on the Hidden Secret North and is exposed in a long crosscut at the 71ft. level on that lease. Of these two series, the first certainly, the second most probably, becomes graphitic at

Fig. 6.

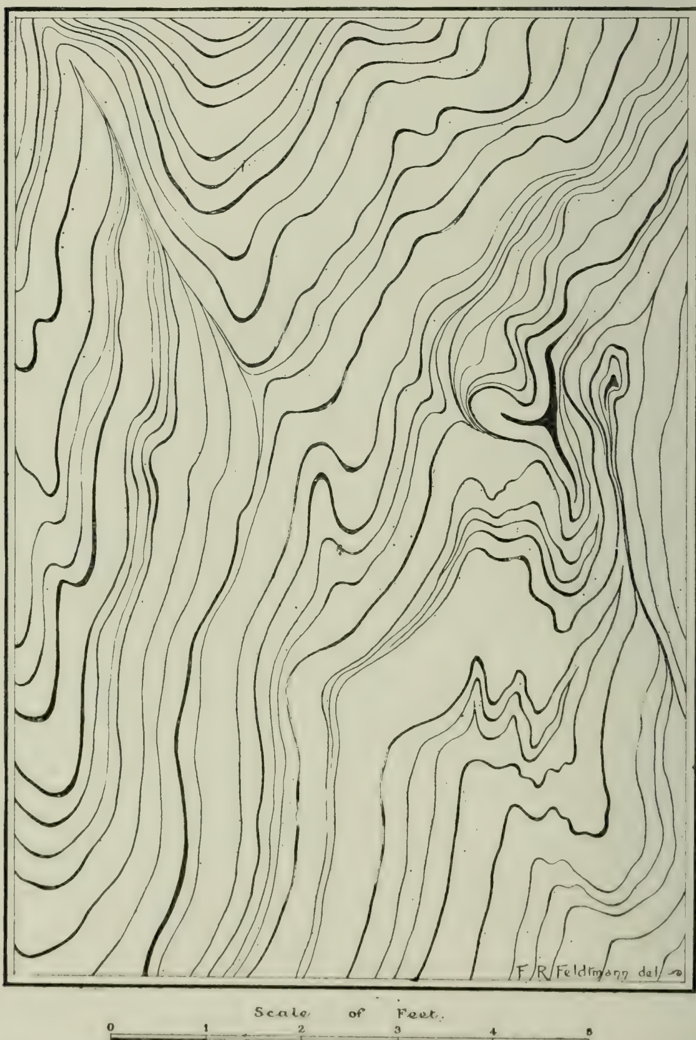


GML 4464E LUCKNOW — Shaft near W boundary — Cross Section showing Jasper Qfe. with contorted slaty laminæ and lenses of flinty quartz Q; sheared zones S, in bleached dolerite greenstone Ac1 (oxidised O Ac1) oxidised fuchsite-carbonate-quartz rock O. Mgf

depth. Another short lens of jasper, composed of finely laminated grey siliceous bands occurs on the Milanese G.M.L. 4293E; since being mapped by the writer its outcrop has been covered by the slimes dump of that mine.

Running through G.M.Ls. 1623E and 213E, on the eastern wall of the south-west branch of the main albite-porphyrite dyke, is another jasper; the workings on this were inaccessible.

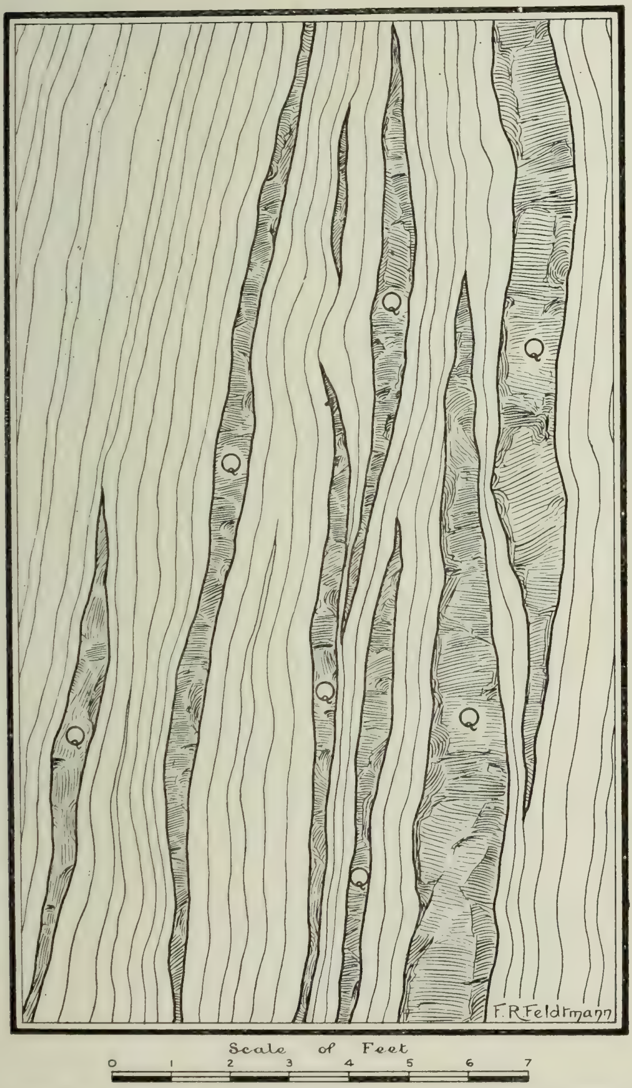
Fig. 7.



G.M.L. 3771E — SONS OF GWALIA — South Shaft, 99 Ft. Level, E. X cut Cross Section showing contorted laminæ of "Jasper"

A jasper very similar in appearance to that of the Milanese is found on G.M.Ls. 4485E, 4368E, and 4037E; it probably joins the

Fig. 8.



DEVON CONSOLS G.M — 149 Ft Level, South drive.
a Sketch Plan of 'Jasper' showing irregular lenses of brown flinty quartz Q, in grey, slaty, siliceous laminæ.

Westralia United main lode a little north of the main shaft, for coarse jasperoid lenses occur associated with the lode south of the shaft, and graphitic seams are found west of the lode at the bottom level of the mine.

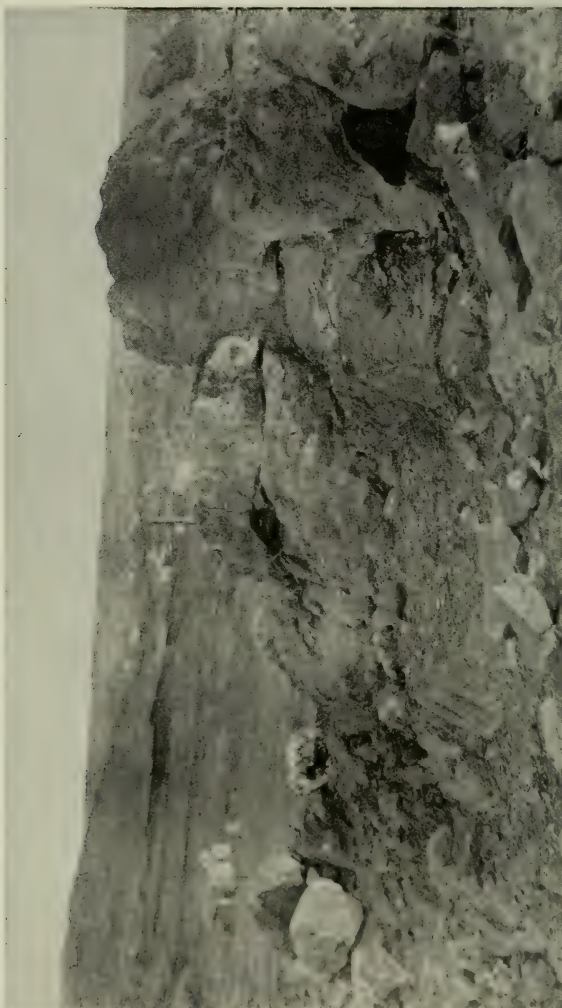


Fig. 9.

Neg. F190.

Photo: F. R. Feldtmann.

Showing outcrop of jasper between the Hannan's Reward N. and Lady Elizabeth leases.

A persistent series of jasper lenses occurs between the Hannan's Reward-Mt. Charlotte leases and Williamstown, closely associated with the previously mentioned band of fuchsite-carbonate-quartz rock and series of albite-porphyrite dykes; what is apparently the northernmost lens of this series is exposed in the workings from a

shaft on the western boundary of the Bonnie Lass G.M.L. 796E, but it is best seen in the east crosscuts from the "Charlotte" main shaft at the 190ft. and 290ft. levels (Plate III.). The section shown in the latter crosscut—from which a number of specimens were taken —is particularly interesting, and a description may be given here. As one goes west from the face of the crosscut, the fuchsite-carbonate-quartz rock [**13454**] becomes greyer in colour, and has apparently been highly sheared and brecciated, the rock being composed of small dark lenses of flinty appearance, but largely composed of carbonates with some quartz and chlorite, surrounded by greener, more schistose material composed of the same minerals but with more quartz and less carbonate; fuchsite is also present [**13455-6**]. At about 90 feet from the face a zone of grey carbonated pyritic rock with cross quartz veins dipping north at about 30 degrees is met with. West of this, the north drive 102 feet from the face of the crosscut is in a band of very pale grey schist composed of carbonates, sericite, and quartz [**13460**]. Within this is a narrow irregular band of greyish-black graphitic schist [**13459**] composed of quartz, sericite, with chlorite and rutile, and innumerable fine carbon particles. According to Mr. Farquharson, the form of the sericitic aggregates suggests former felspars and, with the quartz, give the rock a porphyritic appearance, suggesting that it may represent a highly sheared portion of the albite-porphyrite described later. West of the drive a very hard, pale grey, blocky and slightly schistose rock [**13461**] with some green angular inclusions is met with; this is undoubtedly a carbonated and sericitised form of the albite-porphyrite.

Between this and the small south drive is a completely crushed, grey, carbonated rock, probably derived from a greenstone.

Opposite the small drive is a thick lens of white quartz, with fairly fresh albite-porphyrite on its eastern side, and forming the west wall of the drive is a thin graphitic seam, apparently marking the junction between the albite-porphyrite and a pale grey coarse and highly schistose rock [**13464**] with numerous pyrite cubes and with irregular lenses of white quartz roughly parallel to the shear planes; this rock has already been mentioned under the bleached greenstones. West of this is a fairly fine-grained, pale grey schistose rock [**13465**] with numerous small greenish and a few larger and darker grey rounded inclusions. The origin of this rock, which is largely composed of carbonates, sericite, chlorite, and quartz, is doubtful; it may have been either the quartz-dolerite greenstone or the albite-porphyrite; a well-marked vertical plane, probably a fault line, and striking almost north and south, forms the western wall of this last rock, and on the western side of the wall there is an abrupt change to a dense, hard, dark-grey, fine-grained massive, but jointed rock [**13466**], undoubtedly the quartz-dolerite greenstone.

Table I.—*Analyses of Rocks from East Crosscut, 290ft. Level, and West Crosscut, 388ft. Level, Charlotte Shaft G.M.L. 211E.*

Analysis No.	1	2	3	4	5	9	7
G.S.M.	13454.	13459.	13461.	13464.	13466.	13472.	13473.
Rock	Fuchsite-quartz-carbonate rock.	Graphitic schist.	Carbonated albite-porphyrite.	Bleached greenstone.	Quartz-dolerite greenstone.	Quartz-dolerite greenstone with tourmaline.	Quartz-dolerite greenstone.
Locality	290ft. Level, Face E. Crosscut.	290ft. Level, S. Drive.	290ft. Level, E. Crosscut 117ft. W. of Face.	290ft. Level, E. Crosscut 144ft. W. of Face.	290ft. Level, E. Crosscut 166ft. W. of Face.	388ft. Level, N. Drive off W. Crosscut.	388ft. Level, Face of W. Crosscut.
SiO_2	36·08	74·89	60·62	38·27	43·63	39·41	42·15
Al_2O_3	4·47	14·56	10·96	14·09	12·77	11·97	11·26
Fe_2O_3	·19	1·62	·73	·33	·57	·56	·96
FeO	8·63	·51	2·04	5·54	11·08	9·02	9·51
MnO	·19	·09	·37	·24	·25	·22	·28
MgO	17·05	·71	5·57	4·10	5·11	6·03	6·28
CaO	4·65	·10	5·32	7·54	7·61	10·06	9·05
Na_2O	·29	1·86	1·86	1·35	3·02	·54	2·20
K_2O	1·26	1·04	1·56	3·38	·40	2·14	·22
H_2O +	1·02	2·11	2·05	1·33	2·75	1·21	2·40
H_2O —	·20	·30	·22	·13	·08	·07	·10
TiO_2	·26	·61	·38	1·31	·82	1·31	·82
CO_2	25·64	·12	8·32	11·58	11·58	15·46	13·81
C	..	·18	..	..	..	..	..
P_2O_5	·07	·07	·16	·11	·08	·04	·08
FeS_2	·10	·97	·32	10·49	·22	2·28	·44
Cr_2O_3	·45	..	·01	..	..	..	·01
V_2O_3	Trace	..	..	..	..	..	..
B_2O_3	·01	..	..	·65	..	·13	·05
F	..	..	..	·19	..	..	..
Total	100·56	99·74	100·49	100·63 Less O = F ·08 100·55	99·97	100·45	99·62
Sp. Gr.	2·94	2·69	2·75	..	2·83	2·89	2·86
Analyst	E. S. Simpson.	H. Bowley.	H. P. Webb.	E. S. Simpson and H. Bowley.	H. Bowley.	H. Bowley.	E. S. Simpson.

A variety of the jaspers somewhat different to the foregoing examples is found on the North Collier G.M.L. 4482E (*vide* Bull. 51, pp. 48-9, and Figs. 25 and 26), apparently in a small area of fine-grained greenstone surrounded by fine-grained amphibolite. On the surface this jasper resembles the commoner varieties, but at the 65ft. and lower levels it is represented by a very pale grey—almost white—clayey, finely laminated, somewhat fissile body, composed mainly of kaolin, sericite, and quartz, with some iron hydrate and possibly a little chlorite, while small crystals of tourmaline are extremely common. This rock, as seen underground, being so different to the hard siliceous outcrop, the owners of the lease imagined it to be a different formation. The surface rock had undoubtedly undergone further silicification by surface waters in a manner similar to the formation of laterite deposits. Associated with the jasper, on its western side, and with a slightly different strike to that of the main body, was a seam of dull greyish-black material described by the owners as an "indicator" vein, the best values occurring at its junction with the main body. This "indicator" was composed chiefly of kaolin coloured by finely divided graphite and containing numerous small crystals of tourmaline; associated with the vein, on fractures and between the cleavage planes, was much chloropal (Fe_2O_3, $3SiO_2$, $5H_2O$). It is probable that much of the gold in the shoot or "pipe" on this mine was deposited through the agency of vadose waters coming in contact with the "indicator."

A somewhat similar jasperoid formation, apparently without the silicified cap, occurs near the junction of the fine-grained amphibolites and the dolerite greenstones south of the Transcontinental Railway line.

Auriferous cross quartz veins are frequently associated with the jaspers; they seldom cut completely across the latter, but are usually found cutting into them a few feet, suggesting that these veins are younger than the jaspers. Similar occurrences were seen by the writer at Southern Cross, where also the occurrence of lode formations on the footwall of the jaspers appears to confirm this view. Moreover, Mr. E. de C. Clarke, in dealing with the relation of the quartz reefs and the jaspers at Sandstone and Hancock's,* after describing how the former cut across the latter, arrives at the same conclusion. It must be admitted, however, that some of the minor graphite seams found cutting across the carbonated rocks—for example, in the "Charlotte" shaft east crosscuts—have the appearance of being younger than the latter; nevertheless it is possible that the carbonation took place at a later date.

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* G.S.W.A., Bulletin No. 62, pp. 41, *et seq.*

Occurrence. From the foregoing descriptions, together with the maps, it can be seen that the graphitic schists, represented in the oxidised zone by the jaspers, are not confined to any one rock, but occur in this area:—

(a) In the Older Greenstones.

(b) At the junction of the Older and Younger Greenstones.

(c) In various members of the Younger Greenstone series.

(d) At the junction of the Younger Greenstones and the albite-porphyrites.

(e) In the albite-porphyrites.

In other words, the solutions from which the graphite was deposited travelled along the then available lines of weakness, whatever the rock. Moreover, the graphitic schists were formed at a period subsequent to the intrusion of the albite-porphyrites and, on the bulk of the somewhat meagre evidence available, prior to the formation of the ore deposits. Gibson, however, regards them as later.*

Origin. An organic origin was usually assigned by earlier writers to the graphitic schists—or "carbonaceous slates" as they have been termed. Later writers, however, such as Simpson, Gibson, Larcombe, Maclaren, and Thomson, are agreed on the igneous origin of the graphite. Cirkel,† after examining the various Canadian deposits, some of which are found in sedimentary rocks, others in igneous rocks, came to the conclusion that in some districts the graphite owed its origin to igneous magmas from which, in this case, granitic rocks had been formed, the mineral in one instance forming part of a pegmatite dyke to the same degree as the quartz or the felspar, and, further, he says:—‡

> "The graphite may have crystallised later than the felspar, but it has certainly crystallised before the quartz, and it was derived from the magma like these minerals."

Other graphitic deposits in igneous rocks, usually of an acid character, are found in New South Wales, Ceylon, etc., so that it is evident that the formation of graphite from the products of an igneous magma is by no means uncommon. Within this area the bands of graphitic schist occur in igneous rocks, and, moreover, in a variety of those rocks, at a very considerable distance from any possible sediments; and, in addition to the main bands of these rocks, the graphite sometimes occurs in narrower seams, evidently original joints or shear planes; it is evident, therefore, that the theory of a sedimentary origin is not tenable as regards the Kalgoorlie graphitic schists at any rate.

* *Loc. cit.*, p. 28.

† "Graphite—properties, deposits, treatment and uses," pp. 87, *et seq.*

‡ *Loc. cit.*, p. 91.

But while it is easy to prove an igneous origin for the graphite, it is a very different question when we come to the manner of its deposition. That the graphite was emitted from the magma in the form of some compound of carbon is most probable, for it is unlikely that the exceedingly high temperature required for its existence in the liquid or gaseous form uncombined was ever attained. Simpson,* discussing the occurrence of methane in graphitic schist in the Great Boulder Proprietary mine, regards the latter as—

"shear zones in the greenstone into which hydrocarbons of volcanic origin have penetrated, depositing finely divided carbon in them during slow combustion. This oxidation may have been at the expense of oxygen in the pores of the rock, or at the expense of ferric compounds capable of reduction to a lower state of oxidation.''

The formula for this would be

$$CH_4 + O_2 = C + 2H_2O.$$

Larcombe,† however, considers that

''the carbon is so closely associated with vein formation, which does not take place at high temperatures, whereas''—he states—''I can so far find no literature to show any reaction for the decomposition of hydrocarbons—with formation of graphite—below 500°C, the temperature expected under the conditions of vein-formation. It is therefore more likely that the methane is formed as an after effect, for the graphites were powerfully slickensided after their formation, though some hydrocarbons may have been left undecomposed.''

He further quotes Weigert's formula—

$$C + 2H_2O = CO_2 + 2H_2$$

reversed below 500°C, and concludes with the opinion—

''that the formation of carbon is due to the deoxidation of carbon oxides that existed in the vein solutions and along the sheared lines.''

Although the graphitic schists are closely associated with highly carbonated rocks, resulting from vein-alteration on a large scale—petrological examination and chemical analyses showed that no carbonates were present in specimens collected by the present writer. In typical specimens these rocks are composed chiefly of cryptocrystalline quartz, with disseminated graphite dust, while the not infrequent occurrence of tourmaline suggests that it was formed at the same time. Mr. Simpson mentioned verbally to the writer specimens in which carbonate crystals were seen, but occurring in such a manner as to suggest a later origin, and it is difficult to understand why solutions containing carbonic acid should at the same time in a few instances deposit graphite, in others form carbonates, apparently under similar conditions. It seems probable on the evidence of the barren shear zones described later, that the period of carbonation, in part at any rate, was later than that of the forma-

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* "Natural gas in the Boulder Mines," G.S.W.A., Bull. No. 42, p. 160.

† "The Geology of Kalgoorlie," Mining and Scientific Press, Vol. III., No. 7, p. 240.

tion of the graphite—on the assumption that the latter preceded the period of ore deposition—although it is probable that carbonation extended over a long period of time, and it appears that in volcanic regions the emission of CO_2 belongs to the later periods of gaseous activity,* whereas that of CO and CH_4 belong to an earlier period. As we have seen, methane has certainly been found associated with the graphitic schists, but whether conditions were such as to permit of the decomposition of hydrocarbons† during the period of the formation of these rocks, there is little evidence to show.

As regards the silica percentage—while analyses of Kalgoorlie specimens show percentages ranging from 60 to 84, those of two from the Sandstone district are, roughly, 54 and 57, while at Southern Cross the percentages range from 45 to 78, the latter being exceptional. On the average the silica percentage is not much higher than that of the average greenstones, while that of the rocks in the vicinity with the exception of a specimen of a carbonate-albite-porphyrite is lower than usual, so that it is probable that most of the silica has been derived from the country rock, although some may have been introduced by the magmatic solutions.

So far, then, as the evidence goes, it seems most likely that at some period subsequent to the intrusion of the albite-porphyrites and prior to the period of ore deposition—though probably without a break between it and the latter—the graphitic schists were formed by the invasion of highly sheared zones in the igneous rocks by highly active and probably somewhat siliceous solutions containing gaseous carbon compounds, possibly oxides, but more probably hydrocarbons such as methane, and that these solutions were derived either from the albite-porphyrite or from the parent magma which gave rise to the latter.

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* F. W. Clarke, "The Data of Geological Chemistry," U.S.G.S., Bull. No. 491, pp. 275-6.

† Mr. E. S. Simpson has suggested to the writer the deposition of the graphite from the action of acetylene (C_2H_2) on the ferric compounds with the formation of methane, free carbon and water.

TABLE II.—*Analyses of Rocks from the North End, Kalgoorlie.*

Analysis No.	1	2	3	4	5	6	7	8
G.S.M.	11033.	13451.	13773.	11008.	10436.	13473.	12731.	11029.
Rock	Fine-grained amphibolite.	Fine-grained greenstone.	Fine-grained greenstone.	Quartz-dolerite amphibolite.	Pegmatitic amphibolite.	Quartz-dolerite greenstone.	Actinolite-zoisite amphibolite.	Dolerite greenstone.
Locality	G.M.L. 4370E.	G.M.L. 4063E, Fair Play Extended.	G.M.L. 4230E, Mt. Ferrum Consols.	G.M.L. 211E, Mt. Charlotte.	G.M.L. 3770E, Eaglehawk United.	G.M.L. 211E, Mt. Charlotte.	G.M.L. 4385E, A1.	G.M.L. 4088E, Bonnie Play.
SiO_2	51·72	50·05	49·81	47·12	44·17	42·15	52·37	42·65
Al_2O_3	14·63	12·77	12·38	16·18	10·57	11·26	13·90	4·69
Fe_2O_3	2·02	1·12	·78	3·23	9·20	·96	2·37	·61
FeO	8·26	7·86	7·03	6·90	10·92	9·51	7·41	7·64
MnO	·48	·34	·24	·45	·51	·28	·24	·48
MgO	7·50	6·51	5·04	7·23	4·56	6·28	7·99	15·22
CaO	8·10	8·68	6·91	13·80	9·12	9·05	10·81	7·94
BaO	..	..	..	..	·01	..	..	..
Na_2O	2·42	1·34	1·10	1·54	1·94	2·20	1·52	·30
K_2O	1·38	·48	1·74	·11	·16	·22	·06	·06
H_2O +	2·94	4·42	2·82	1·92	2·28	2·40	2·68	1·32
H_2O —	·06	·13	·02	·09	·16	·10	·10	·09
TiO_2	·51	·33	·60	·72	4·99	·82	·77	·20
CO_2	·05	6·31	10·92	..	·35	13·81	·12	18·07
P_2O_5	·11	·14	·10	·15	·40	·08	·11	·19
FeS_2	·19	·02	·30	·22	·26	·44	·26	·30
Cr_2O_3	·02	·05	·03	..	..	·01	..	·40
V_2O_3	·06	·06	·03	·01	·19	..	..	..
B_2O_3	..	..	..	..	..	·05	..	..
Total	100·45	100·61	99·85	99·68	99·79	99·62	100·71	100·16
Sp. Gr.	2·94	2·79	2·85	3·10	3·27	2·86	3·00	2·84
Analyst	H. Bowley.	E. S. Simpson.	H. Bowley.	H. Bowley.	E. S. Simpson.	E. S. Simpson.	H. Bowley.	E. S. Simpson

TABLE II.—*Analyses of Rocks from the North End, Kalgoorlie*—continued.

Analysis No.	9	10	11*	12	13*	14	15	16
G.S.M.	2117.	11003.	12240.	13424.	3391.	10913.	2943.	12331A.
Rock	Lustre-mottled amphibolite.	Hornblendite.	Talc-chlorite carbonate rock.	Talc-mesitite rock.	Serpentine.	Fuchsite-quartz-carbonate rock.	Hornblende-quartz porphyrite.	Albite-porphyrite.
Locality	G.M.L. 1219E, Gt. Boulder No. 2 South.	G.M.L. 4157E, Hannan's Hope Extd.	G.M.L. 4406E, Hyman.	G.M.L. 796E, Bonnie Lass.	G.M.L. 4320E, Ivy.	G.M.L. 440E, Hyman.	W.R. 3398.	G.M.L. 4406E, Hyman.
SiO_2	44·23	46·26	35·90	36·52	47·44	33·80	65·66	69·02
Al_2O_3	10·89	9·01	13·48	5·42	6·65	5·72	13·55	15·92
Fe_2O_3	·13	·67	7·04	·86	·76	·40	1·63	·58
FeO	14·22	10·41	4·12	9·88	6·78	8·70	1·56	1·90
MnO	1·60	·56	..	·22	..	·19	·23	09
MgO	11·42	19·65	15·69	23·17	26·68	19·95	1·56	2·63
CaO	10·43	6·94	5·81	4·84	3·39	1·34	5·46	·29
BaO	..	..	..	..	..	..	·03	..
Na_2O	1·02	·30	·26	·38	·33	·30	5·00	7·48
K_2O	·20	·10	2·00	·10	..	2·11	1·96	..
H_2O + ...	4·25	4·42	4·71	4·42	5·68	·59	·46	1·02
H_2O —	·22	·14	1·84	·18	·78	·09	·10	·28
TiO_2	·06	·54	..	·20	..	·33	·50	·57
CO_2	1·29	·20	9·22	13·78	2·06	25·98	1·58	·14
P_2O_5	..	·21	..	·14	..	·11	·54	·28
FeS_2	·26	·19	..	·17	..	·24	·02	·11
Cr_2O_3	..	·20	..	·42	..	·50	·01	..
V_2O_3	..	·10	..	·02	..	Trace	·01	..
B_2O_3	..	..	..	..	..	ZrO_2 = ·02	ZrO_2 = ·02	..
Total	100·22	99·90	100·07	100·72	100·55	100·37	99·88	100·31
Sp. Gr.	3·00	2·96	..	2·88	..	2·97	2·75	..
Analyst	C. G. Gibson.	H. Bowley.	..	H. Bowley.	..	E. S. Simpson.	H. Bowley.	..

* Partial Analysis only.

III.—THE ORE DEPOSITS.

The ore deposits of the North End may be classified as follows:—

1. Primary ...	A.—Lode formations ...	(a) Quartzose. (b) Schistose.
	B.—Cross quartz veins.	
2. Secondary ...	A.—Impregnations in the zone of oxidation.	
	B.—Detrital deposits ...	(a) Eluvial. (b) Alluvial.

1. A.—The Lode Formations.

The subdivision of the lode formations within this area is no easy matter, particularly as investigations were, in many instances, confined to the oxidised zone. There is a mergence of the different types into each other, and any one deposit differs in minor particulars from the others. On the whole the most important factors seem to be the original composition of the country rock and the degree of alteration to which it has been subjected, the latter depending partly on the amount of shearing it has undergone, partly on the strength and quantity of the ore-bearing solutions.

The following appears to be the simplest and most natural subdivision:—

(a) Quartzose lode formations.

(b) Schistose lode formations.

(a) *The Quartzose Lode Formations.*

These appear to be confined to the quartz-dolerite greenstones or the bleached forms of those rocks. As mentioned by Gibson,* they differ from those of the schistose type in the greater amount of replacement of the original minerals by crypto-crystalline quartz in the lodes of the former type, whereas those of the latter type are largely carbonated and their schistose character is more apparent—this being largely obscured in the quartzose lodes by metasomatic replacement. The greater quantity of silica present in the lodes of this type is due, no doubt, not only to the more complete alteration of the country rock, but also to the greater quantity of silica present in the original rock—this type being, as already stated, confined to the less basic members of the Younger Greenstones.

Practically the only example of the quartzose lodes within this area is the Golden Zone line—one of the most persistent lode channels of the North End, described in Bull. 51, p. 17. As stated in that report—

Loc. cit., p. 49.

"the main body of this lode consists chiefly of crypto-crystalline quartz and is the result of complete metasomatism of the country rock along a line of shearing. The lode passes insensibly into the country rock, the latter having been subjected to metasomatic action for some distance beyond the ore body."

The country rock in the vicinity of the ore-body is composed chiefly of carbonates, quartz, sericite, chlorite, albite, and iron ores. It should be mentioned that this lode is not so typical an example of the quartzose lodes as some of those on the Western side of the Golden Mile.

(b) *The Schistose Lode Formations.*

These are found both in the Older and Younger Greenstones, also at the junctions of the rocks of the two series and at the junctions of the latter with the albite-porphyrites. As these formations in some of the rock types present features differing from those in other types, the lodes of the different rocks will be discussed seriatim.

Schistose Lodes in the fine-grained Amphibolites. Only one formation carrying values apparently in the fine-grained amphibolites was seen by the writer, namely, on the eastern boundary of former G.M.L. 449E, Colleen Bawn (Fig. 10). The country rock was, however, too decomposed for determination and may have been the corresponding greenstone, which certainly occurs about 10 chains to the west. The formation was particularly flat in dip, and probably joins the northern portion of the Westralia United lode channel at a depth of, roughly, something over 450 feet, beneath the Kanowna road. Values had evidently been obtained in this formation, since a little stoping had been done at the 110ft. level. As the work was not carried below the oxidised zone, no description can be attempted, but it probably bears the same relation to the lodes of the fine-grained greenstones as the schistose formations of the quartz-dolerite amphiboltes bear to those in the quartz-dolerite greenstones.

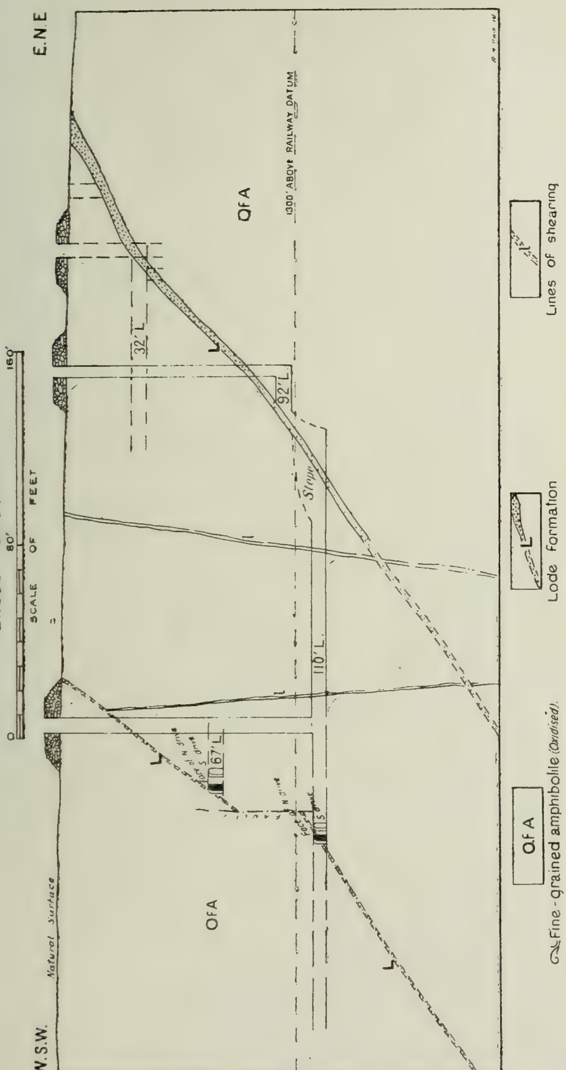
Schistose Lodes in the fine-grained Greenstones.—There are a fair number of schistose lodes in the fine-grained greenstones; most of these seem to join a main channel—previously mentioned in the description of these rocks—running close to the junction of the Older and Younger Greenstones.

Among the most typical formations in the fine-grained greenstones may be mentioned the Isabel and Brown Hill Junction lodes (Plates IV. and V.). In each case there are two main parallel ore channels. In the Brown Hill Junction they appear to join at a depth of about 240 feet in the cross section through the main shaft; another parallel line, apparently poorer in value, occurs about 50 feet east of the main line in this mine. The main levels of the

Isabel were unfortunately inaccessible, so that no description of the lode below the oxidised zone can be attempted. Along the Brown Hill Junction main line the sulphide zone was only encountered at

Fig. 10.

G.M.L 4490E COLLEEN BAWN.
CROSS SECTION



Showing lode formation in fine-grained amphibolite.

the southern end of the drive at the 199ft. level in the former Mt. Ferrum Consols—the lower levels in this mine also being under water. The lode had been largely stoped out at the 199ft. level,

but from the rock in the vicinity and specimens on the dump, it was probably composed of highly schistose matter consisting largely of carbonates—probably chiefly ferriferous dolomite—with some crypto-crystalline quartz, sericite, probably some albite, and a fair amount of pyrite. In some specimens from the dump a "cockade" structure was shown by small areas of crypto-crystalline quartz surrounded by carbonates and fine pyrites—the latter sometimes displaying a pyritohedral habit. Some fragments of white quartz veins—probably cross veins—surrounded by ferriferous carbonate—some well developed crystals of the latter occurring in the quartz—and a little coarse pyrite, were also found; tourmaline needles were visible on some of the shear planes.

In the oxidised zone a good many seams of manganese oxide are visible; this feature appears to be fairly characteristic of the fine-grained greenstones, although analyses show but little difference in the percentage of MnO in these rocks and the Younger Greenstones.

As has already been stated, the calc-schists occur in this area only as local modifications of the fine-grained greenstones in the vicinity of the lodes, from which they are distinguished only by the greater degree of metasomatic alteration in the latter. On The Mile, where vein alteration has extended over a wide area, they cover a big extent of country, and lode formations are found apparently confined to them—as distinct from the greenstones.

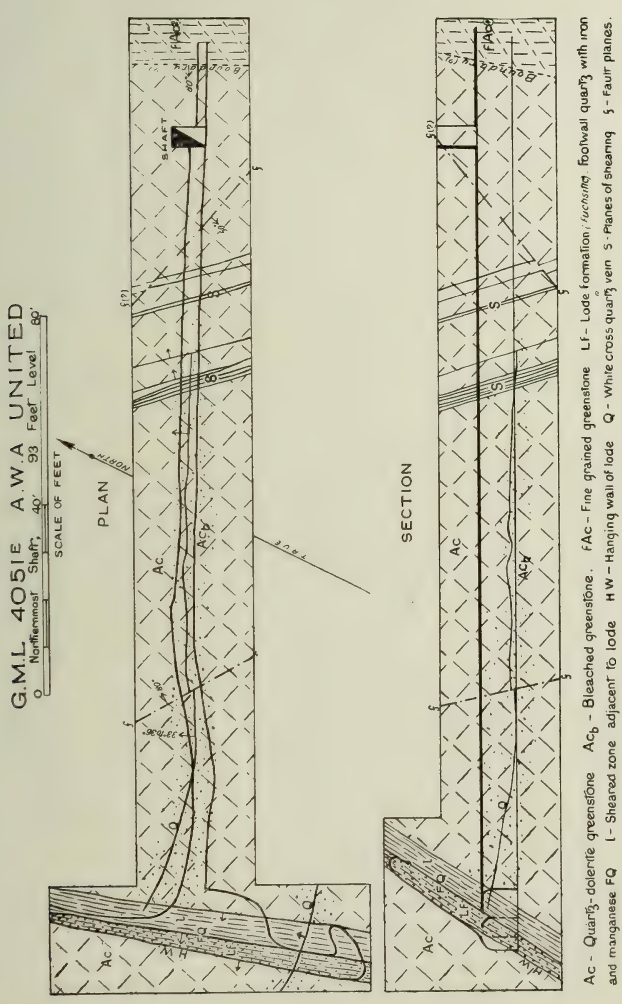
Schistose Lodes at the junction of the Older and Younger Greenstones.—The boundaries between the two Greenstone series would naturally form lines of weakness affected by dynamic action subsequent to the intrusion of the Younger series. That this has been so in the case of the junction of the Younger Greenstones and the eastern belt of the Older series can be seen by a glance at the map. Within the main channel, formed by this junction line, are the Westralia United lode and the thin persistent line mentioned as passing through the Isabel, Creswick, and A.W.A. United (Figs. 11 and 12).

In the case of the Westralia United lode (Fig. 12) the cross section through the main shaft on that mine shows two lode lines, roughly parallel in dip, within the main channel; they appear to junction further north; the western and main line splits near the 231ft. level, and some jasperoid lenses and graphitic seams are associated with the western branch at the 329ft. level. Owing to the altered state of the rock it is impossible to say definitely whether the lode is mainly in the quartz-dolerite greenstone or the fine-grained greenstone, but I am inclined to think the latter. Irregular ore shoots are common in this mine, as may be seen on the longitudinal section (Plate VI.). There were a few lenses of flinty quartz

in these shoots, but in the main the lode consists of highly schistose, carbonated rock—probably more chloritic than is usual with the lodes—with some irregularly distributed fine pyrite.

The Isabel-A.W.A United line (*vide* maps and Fig. 11) is of quite a different character and is more quartzose than usual with the

Fig. 11.

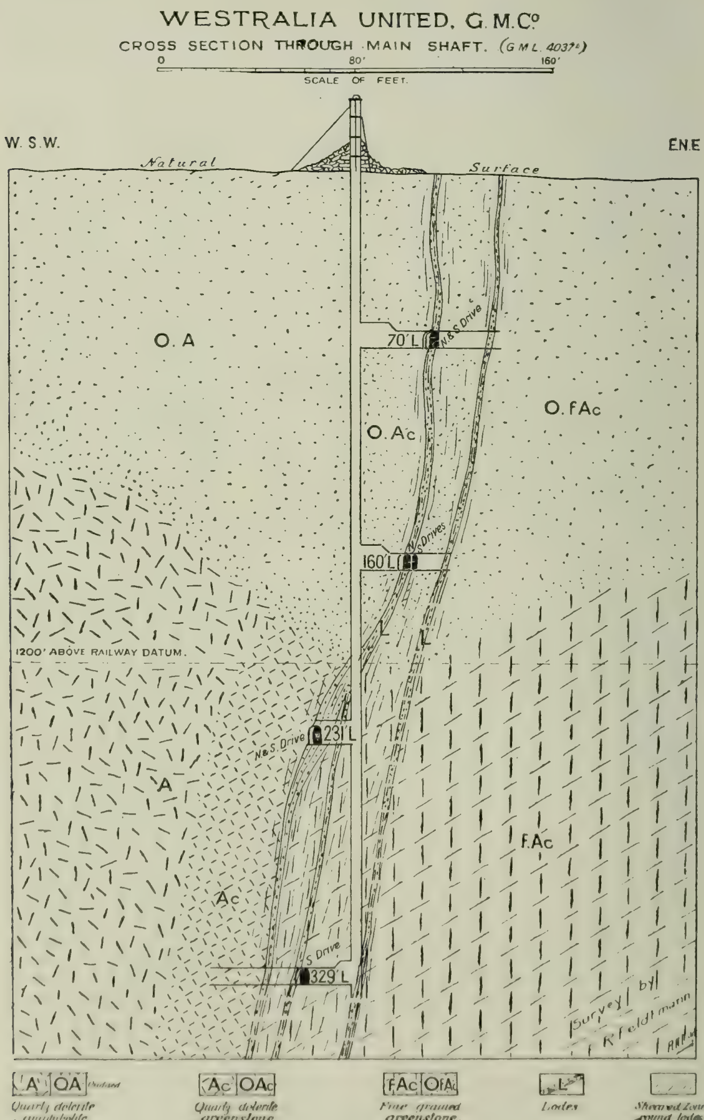


Sketch plan and section, 93ft. level, nothernmost shaft.

schistose formations; it really forms a class by itself, but is discussed here for the sake of convenience. It is more commonly in the quartz-dolerite greenstones than in the fine-grained greenstones at the sur-

face, and appears to dip sharply to the west, away from the junction. In strike it is more nearly north and south than is usual with the lode formations. It is a narrow, usually well-defined body,

Fig. 12.



usually from two to four feet in width—but occasionally pinching to a thin seam—consisting of irregular veins of milky quartz with, in the oxidised zone, much ferruginous and manganiferous matter. One quartz vein was seen by the writer with a width of one foot, in one instance—in this case the quartz was seamed with numerous cross joints carrying manganese oxide. These quartz veins were vughy in places and a fair amount of fuchsite was visible round them. At one point near its southern end, in fine-grained greenstone—in a shaft on former G.M.L. 4450E—this formation presents a most peculiar appearance, consisting of purplish-grey matter, with a marked, apparent flow structure—probably due to brecciation—in which there were numerous creamy white augen. The darker material was found on examination to consist largely of strings of tourmaline grains, between which were small quartz plates in a minute mass of quartz and kaolinic matter, with, in places, some micaceous fibres. A good deal of ferruginous and probably manganiferous matter and some irregular white quartz on the hanging-wall were associated with this breccia. This formation seldom carries payable values except at its junction with the numerous lode formations which run into it from the fine-grained greenstones; such patches have been found in the Creswick and Isabel, and, no doubt, further prospecting would reveal others.

Schistose Lodes in the Quartz-Dolerite Amphibolites.—As mentioned in the description of those rocks, but few lode formations, and those of low grade, are found in the quartz-dolerite amphibolites. As shown in the workings from the old Bohemian Girl and Lady Forrest main shafts (Fig. 13) they consist in the oxidised zone of a few short lenses of flinty quartz in a narrow band of sheared rock, in which the metasomatic alteration appears to be slight and probably extends for a very short distance outwards from the main shear lines. In general, in the oxidised zone these formations resemble the barren shear zones of the Hannan's Reward-Mt. Charlotte, more particularly as the few cross quartz veins encountered have been faulted in places. Their strike, however, is different to that of the barren shear zones but similar to that of the lodes, and it is probable that they represent minor channels near the western margin of the area affected by the auriferous solutions. In this case the faulting of the cross quartz veins would be due to later dynamic stresses, such as those which formed the barren shear zones, causing further movement along the lode channel. An unusual feature is the marked easterly dip. Whatever their origin they are practically barren and consequently of no economic importance.

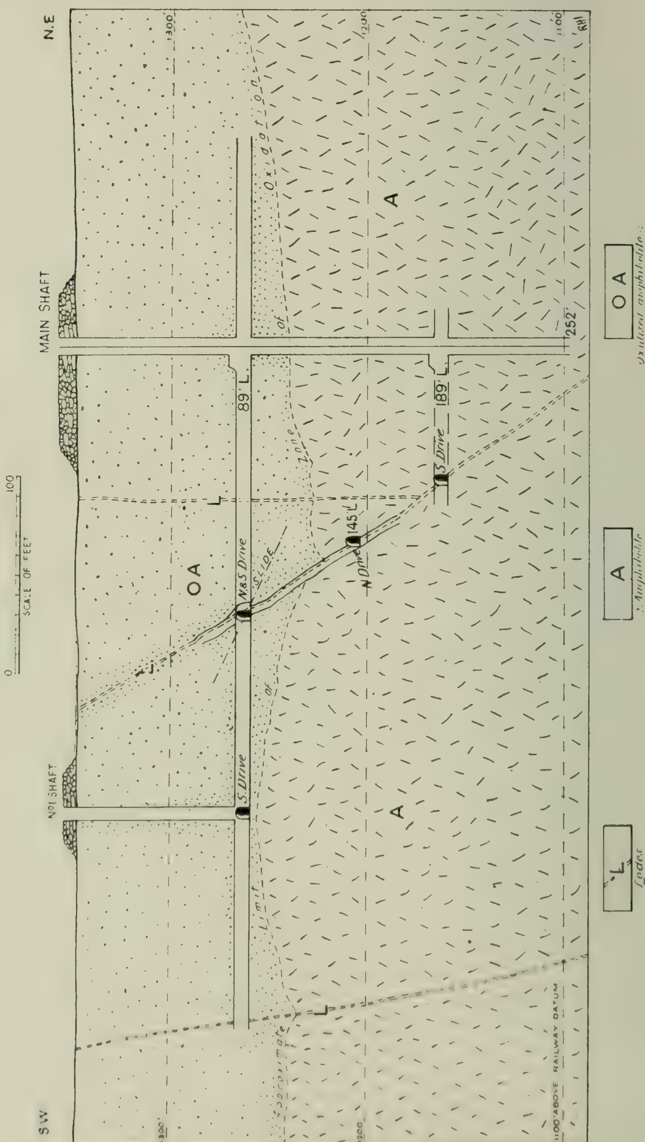
In the case of the formation in this rock in G.M.L. 4524E at Mullingar, the quartz-dolerite amphibolite appears to have been altered by shearing along a narrow band to a talcose schist. This

formation also appears to be low in value; it seems to be rather more quartzose than is usual with the schistose formations and is possibly of an intermediate type.

Fig. 13.

LADY FORREST MAIN SHAFT.

CROSS SECTION.



Schistose Lodes in the Quartz-Dolerite Greenstones.—Lodes of this type are but poorly represented in the quartz-dolerite greenstones, probably the only one being that on the north-eastern slope of Mt. Gledden, in the Maritana G.M. Here, also, examination has been confined to the oxidised zone. Fair values were obtained above the 75ft. level from the main shaft, but how much of this is due to secondary impregnation is impossible to say. A number of cross quartz veins of the usual type were associated with this lode, which, in the oxidised zone, was rather ill-defined. It contained seams of ironstone and quartz, apparently with traces of copper. A good deal of pyrites appears to have been associated with the formation.

It is possible that some of the N.N.W.-S.S.E. striking shear zones in the Hannans Hill and Cassidy's North may be lode formations of this type, but examination below the zone of oxidation is necessary to determine that; they do not appear to carry values except those due to secondary impregnation, and are found to fault the cross quartz veins and, moreover, are closely associated with the N.S. shear zones, so that, on the whole, I am inclined to regard them as belonging to that series in spite of the fact that their strike agrees with that of the lodes. No doubt the compressive stresses that caused the shearing along the N.S. lines, also found relief in the direction of the older lines of weakness.

Schistose Lodes in the Actinolite-Zoisite Amphibolites.—The only formations seen in the actinolite-zoisite amphibolites were two small parallel ones in the dolerite derivatives in the Hidden Secret North. They occur along the same line of weakness as the Hidden Secret lodes, and at their northern end join the previously mentioned N.E.-S.W.-striking jasper. They consisted of a few lenses of flinty brown quartz in a comparatively narrow sheared zone, and were apparently too low in grade for profitable mining.

Schistose Lodes in the Dolerite Greenstones.—In this portion of the field these lodes are best developed in the dolerite greenstones. Both the Hidden Secret and the greater portion of the Fair Play lode channels occur in these rocks. In the former mine there are two main lines of lode, which may be termed the "Hidden Secret" and the "Hidden Secret South" lodes respectively; both are found to branch—the former at its northern end, the latter at its southern.

The rich shoot of ore worked on this mine—in the Hidden Secret lode—has been stoped out, and the writer can give no description of the characteristic minerals from personal observation. Mr. Simpson,* however, gives an analysis and description—in addition to two micro-photographs (plate 15)—of a block of specimen ore from this mine; he states that it was a dark green schistose rock, characterised by a very low percentage of carbonates but unusually

* *Loc. cit.* pp. 68 and 71.

high in pyrite, usually well crystallised; extraordinarily large quantities of gold, silver, and tellurium were also present; notable, also, was the large amount of chromium and vanadium mica. Chalcopyrite and the tellurides hessite (Ag_2Te) and petzite (Au_2Te, $3Ag_2Te$) were also present. Mr. Simpson states that the analysis "was made on a single block of specimen ore of about five pounds weight, and the results may not be typical of the whole ore body." Other tellurides recorded from this mine are coloradoite (Hg Te), tetradymite (Bi_2 Te_3) and altaite (Pb Te). Although in the specimen quoted but little carbonate was present, the country rock in the vicinity of the lode is fairly highly carbonated, and numerous veins —sometimes across, sometimes with the shear-planes—and irregular patches of carbonates were observed in the lode channel; a fair proportion of the carbonate is evidently calcite, from its strong effervescence in cold HCl; these carbonates were sometimes associated with milky quartz. In the altered country in the vicinity of the channel crystals, probably of dolomite, up to one-sixth of an inch in size were developed in places. Some thin lenses of flinty quartz also occur in the lode. Fuchsite was occasionally noticed in the vicinity of the quartz and carbonate veins. A good deal of fine pyrite was present in the lode itself, while in the immediate vicinity there was a marked development of large cubes of pyrite—specimens of over half an inch square being obtained by the writer.

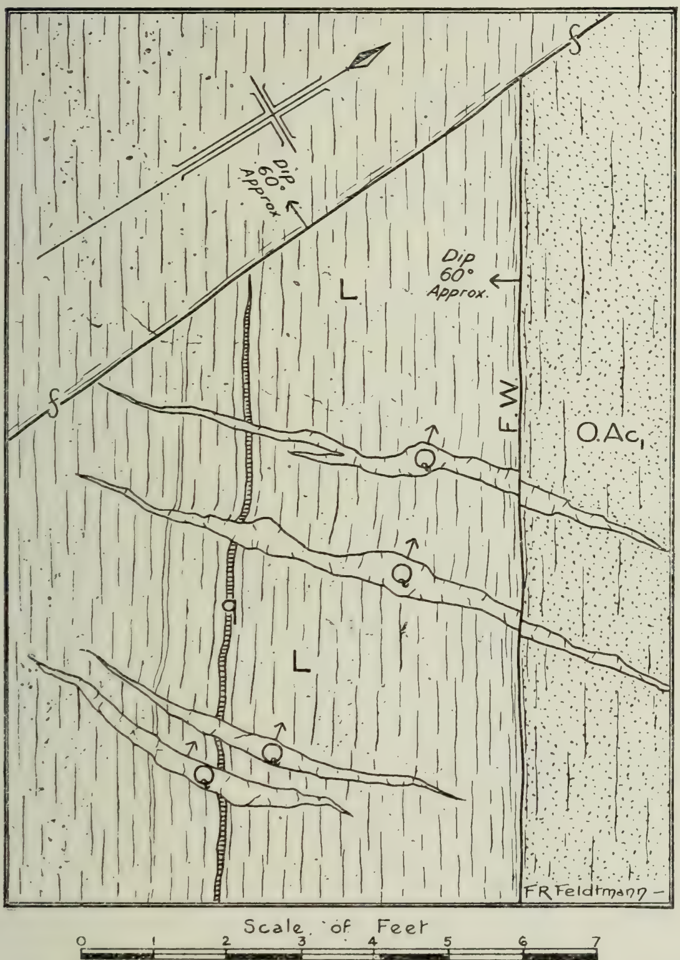
Noticeable in the west branch of the lode at the 89ft. level was a series of short, thick lenses of milky quartz running across but within the lode and dipping to the north (Fig. 14); these are probably due to the filling of contraction cracks within the lode itself, and are of a different character to the thin auriferous cross quartz veins so characteristic of this end of the field; these latter also occur on the mine. There are a number of minor sheared zones, joints, and some small local faults in the vicinity of the lode (Fig. 15).

The rich shoot in this mine, so far as can be judged, occurred at the junction of the east and west branches of the lode, but exactly what shear planes controlled the distribution of the ore it is now impossible to say, owing to the stoping of the shoot itself and the rock in its immediate vicinity. Its form was nearly that of a pipe, or more correctly that of a greatly elongated lens (*vide* Plate VII.), with the longest axis practically vertical; it extended from a depth of 35 feet from the surface to just above the 304ft. level, where a trace of one of the shear planes along which the rich telluride ore occurred can be seen.

Other shoots of good ore, of the usual lenticular character, have been found on the mine, and I can see no reason why other payable shoots should not be found. At the 404ft. level the lode junctions with the fuchsite-carbonate-quartz body.

In the Fair Play the lenticular form of the ore shoots is most noticeable; the shoots pitch to the south, following each other very

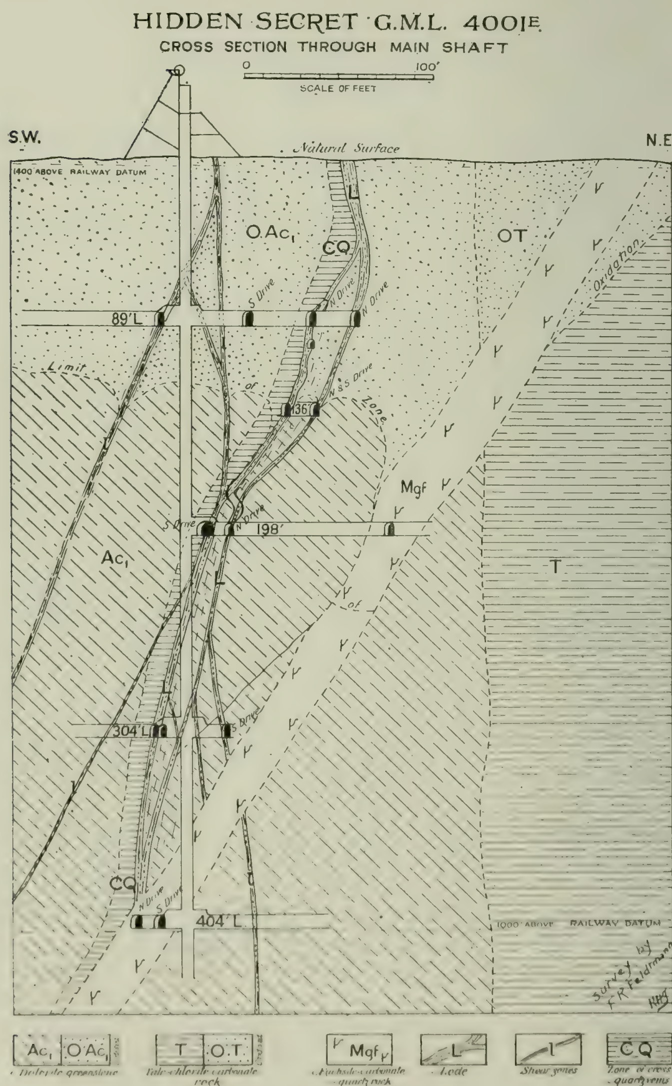
Fig. 14.



HIDDEN SECRET G.M.L 4001^E — 89 Ft Level, N. drive on W branch of lode — Sketch Plan showing cross veins of white quartz Q cutting planes of lode L, with lenses of brown flinty quartz q, but faulted by footwall plane F W, — N-S fault plane § — oxidised dolerite greenstone O.Ac$_1$.

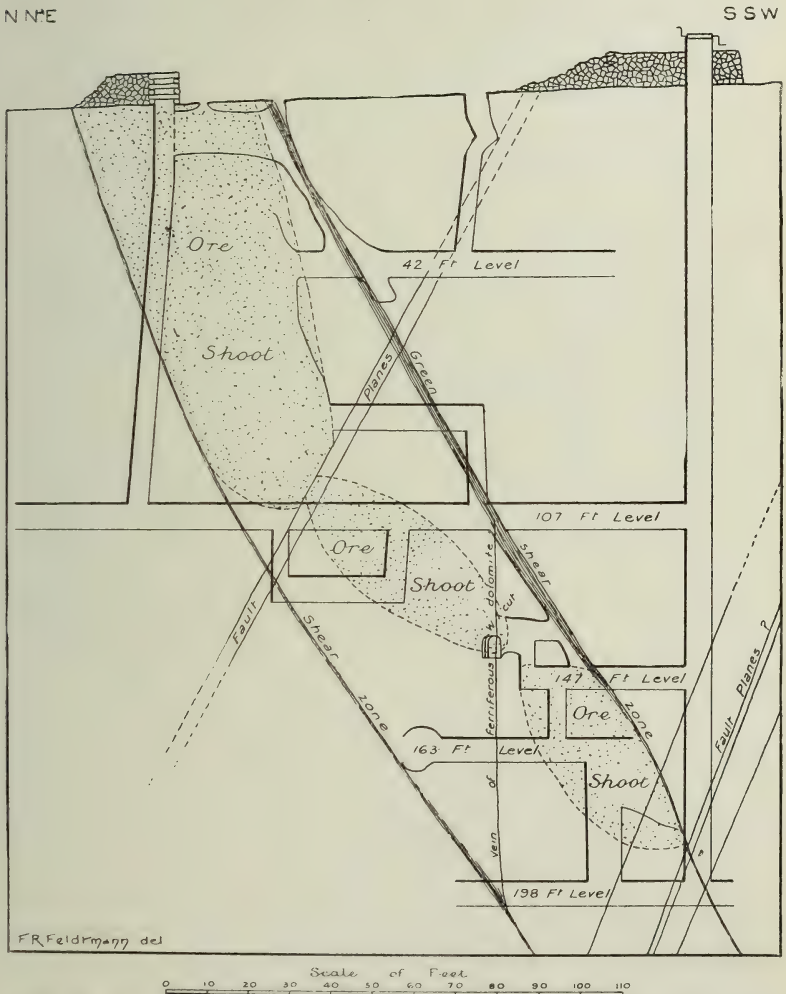
closely. The distribution of the ore seems to have been largely controlled by two more or less parallel shear or fault zones, running across the lode with a strike of about 35° north of west and dipping

Fig. 15.



west of south (Fig. 16). The more southerly and more strongly marked of the two, forming the hanging wall of the shoots, is composed of green, probably fuchsitic and talcose, schist, with some green quartz in places. Between the main shaft and the ladder way the lode splits going north and the line of junction of the two branches has probably had some influence on the ore deposition as the shoots occur close to it. The lode itself is largely composed of carbonates—

Fig. 16.



FAIR PLAY G M. — LONGITUDINAL SECTION SHOWING ORE-SHOOTS.

mainly dolomite—with some sericite, quartz, finely divided pyrite, and a little chlorite, while the analysis* shows a high percentage of chromium and vanadium. Veins of dolomite, running both with and across the lode, are common, and there are some cross veins of quartz and a few seams of pyrite. Tellurides, said to have been petzite and calaverite, have been found in this mine, and some blende was observed at the 162ft. level.

Schistose Lodes in the Talcose Rocks.—No lode formations were observed by the writer in the hornblendites, and, with the exception of those at their junction with the albite-porphyrites—described below—and a few minor formations, apparently unpayable, none were seen in the talc-chlorite-carbonate rocks. Cross quartz veins, chiefly associated with bands of fuchsite-carbonate-quartz rock—such as Smith's lode—have, however, been worked in them.

No lode formations have been found in the small area of talc-mesitite rock.

Schistose Lodes at the Junction of the Greenstones and the Albite-porphyrite.—The best examples of these are the lode running through the Hyman, Mystery, Little Wonder, and Lone Hand leases, and that in the Red White and Blue—the latter is probably the southerly continuation of the former. A detailed description of the former was given in Bulletin 51, pp. 19 and 20, q. v. As stated in that report, none of the accessible workings had been carried below the oxidised zone, so that no description of the characteristic minerals below that zone can be given. This lode occupied a sheared zone at the junction of the main albite-porphyrite dyke and the talc-chlorite-carbonate rock; occasional lenses of fuchsite-bearing quartz were seen, and the lode is probably closely associated with a band of fuchsite-carbonate-quartz rock, which in this case, would be a bleached form of the talc rock; there were a number of auriferous cross quartz veins associated with the lode; a good deal of tourmaline was present, in flat veins in the albite-porphyrite, and on shear planes in the latter.

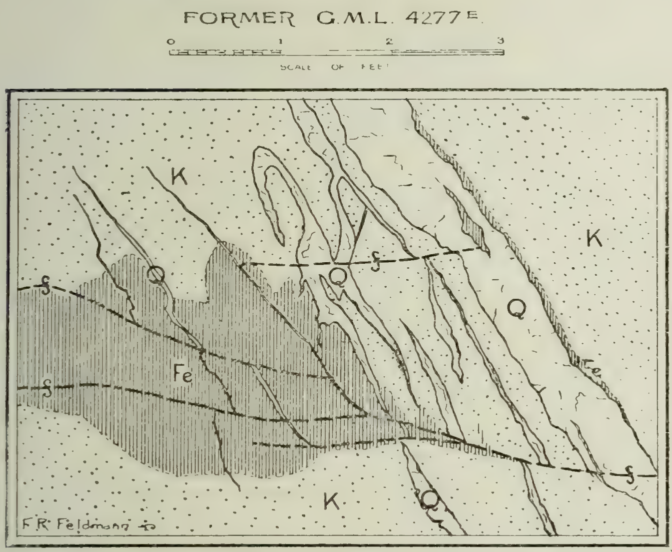
B.—The Cross Quartz Veins.

Cross veins of quartz are of extremely common occurrence at this end of the field. Though found almost everywhere in the main dyke of the Younger Greenstones, they are most particularly developed in the quartz-dolerite greenstones, and, perhaps to a slightly less extent, in the dolerite greenstones. Though persistent in length and depth, they are usually only one or two inches in width, but varying from a fraction of an inch up to about four inches. A few in the fine-grained amphibolites north of the Sir John and east

* Bulletin No. 42. Table III., G.S,M., 10847A.

of the Broad Arrow Road were seen with a width of two feet, also one south of the Hannans Find (Fig. 17), but these were exceptional. In some instances these veins occur as vein systems rather than simple veins.

Fig. 17.



Showing compound cross quartz veins -Q in oxidised epidiorite (*group a*) now represented by kaolinised matter -K and ferruginous matter Fe some local faulting § has affected the stringers

There are two series of these veins, the one striking approximately E.N.E.-W.S.W., with a dip usually varying from 60° to the north to verticality, the other striking more nearly E.-W. and dipping to the north at an angle, usually between 30 and 40 degrees. In general appearance the veins of the two series closely resemble each other, being composed of milky-white quartz, with a slightly oily lustre. Below the oxidised zone they are "frozen" on to the country rock, which is usually altered to a bleached, pyritic, carbonate-quartz rock—"bleached greenstone"—for a short distance from the vein (*vide* Fig. 1); the pyrite, which is fairly coarse, is usually thickest close to the veins, occasionally occurring in them. Both series carry good values; there being little to choose between them in this respect—the veins of the one series being the better in one mine, those of the other in another. The gold is free and usually coarse. In one specimen [2772], collected by Mr. W. D. Campbell from the 500ft. level of the "Reward" shaft on G.M.L. 97E, two tellurides, a pale and a dark variety, occur in the quartz; these were

present in too small amounts for accurate determination, but the paler variety was most probably calaverite, the darker petzite. Tellurides are also said to have occurred in a cross vein in the Fair Play Extended. These are the only occurrences of tellurides in these veins recorded, and are important as showing that the fissures were most probably filled at the same time as the sheared zones along which the lode formations were formed. In another vein, on the south-east boundary of the Cassidy Hill lease, a small rich patch of gold was associated with galena, coarse hæmatite pseudomorphs after pyrite and coarse patches of a ferriferous carbonate—the occurrence of galena is unusual; the only other instance, so far as the writer knows, where this mineral has been recorded at Kalgoorlie, was in a specimen [**10956**] from the Hidden Secret lode.*

The steeper series of cross veins is best developed in G.M.L. 211E, where the average dip is about 70°. In this lease the veins are very close together and in the oxidised zone, where the intervening country carries low values due to impregnation by surface solutions, both veins and country have been taken out together on the open cut system, over a very large area. Further south, in the Hannans Hill G.M.L. 97E these veins are practically vertical or dip slightly to the south. In the Bonnie Lass, east of G.M.L. 211E, the veins are nearly vertical and the occurrence of vein systems is common (Fig. 18). In the Cassidy Hill, south of the Hannan's Hill, the veins of this series usually dip south at about 80°.

The flatter series are best developed in the Hannan's Hill and Cassidy Hill leases, where they appear to carry better values than the vertical veins; as with the steeper series the dip is variable (*vide* Plate VIII.), but as already stated, usually between 30° and 40°. Two veins which appear to belong to this system, but differ somewhat in strike, occur, one at the southern end of the Hannan's Hill, where it has been worked from a shaft connecting with the southernmost west crosscut—west of Brownsword shaft—at the 80ft. level; the dip of this vein is very shallow (about 12°), and the strike about 30° north of west; the other is in the Cassidy Hill lease at the end of the west crosscut from No. 1 shaft at the 55ft. level (*vide* Plate VIII., the "19dwt." vein)—the dip of this vein is about 45° and the strike about 24° north of west.

Although the two series of fissures in which these veins were formed were filled at the same time, they appear to have originated at different periods. The steeper series seems to have been the earlier, being apparently faulted in places by the flatter. The former series strikes at right angles and appears to be complementary to the sheared zones of the lode formations.† The flatter veins, on the other hand, most probably represent a series of overthrust faults resulting from pressure from the north at a later period than the

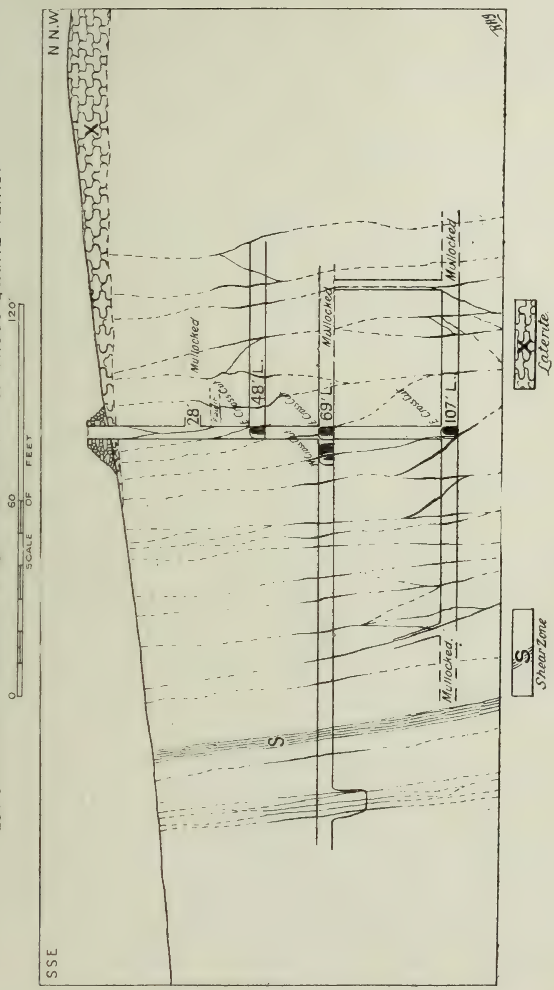
* Bulletin No. 42, p. 93. † Bulletin No. 51, p. 22.

probable W.S.W.-E.N.E. pressure which caused the shearing along the lode channels and the fissures of the steeper veins. Both series were probably filled after a period of relaxation, following on the period of compression, had opened the fissures to some extent.

Fig. 18.

BONNIE LASS G.M.L. 796E.

LONGITUDINAL SECTION SHOWING SYSTEM OF CROSS QUARTZ VEINS.



Although these veins have been worked to such an extent in the oxidised zone, comparatively little work has been done on them below that zone, although they maintain their values at depth; since, as already stated, being frozen on to the country rock and, where close together, the intervening country having to be taken out

as well, much greater labour and expense are entailed than in the oxidised zone.

In addition to the veins of these two series, others of fairly similar character occur, sometimes striking with the country, sometimes across it—the dip of these varies considerably—they may be connected with those of the first series. In addition, mention should be made of the nearly horizontal tourmaline-bearing veins associated with the albite-porphyrites*; these do not appear to carry values and probably represent contraction joints in the albite-porphyrite.

2.—SECONDARY ORE DEPOSITS.

A.—Impregnations in the zone of oxidation.

These are best developed in connection with the cross quartz veins As already mentioned, where these veins occur close together, the intervening country often carries sufficient gold to be payable when both veins and country are worked together on a large scale. This gold content is due to circulating vadose waters having dissolved a portion of the gold of the cross veins—usually in the vicinity of a shear zone or fault plane which would form a channel for these waters—to redeposit it over a wide area near the surface.

The fact that in the Reward-Mt. Charlotte mine the leaders carry practically no gold in the immediate vicinity of the N.S. shear zones—which, in this case, have formed the channels for the vadose solutions—confirms this view. Some idea of the extent to which this secondary impregnation has taken place may be formed from the size of the open-cuts in this mine and the adjoining Cassidy's North. In the Gordon G.M.L. 4539E (Cunard mine), further north along the same line of country, both leaders and country rock have been stoped out to a large extent, but in this case the leaders do not seem to have been sufficiently rich or numerous to make the undertaking profitable. In the Devon Consols the country has also been impregnated to some extent round the cross veins in the vicinity of the big jasper formation.

Similar impregnations occur associated with the lode formations, and in this case the lodes themselves have probably acted as channels for the surface waters. This impregnation near the lodes is particularly noticeable in the infralaterite, for example, at Mt. Ferrum and Mt. Percy—the former in the vicinity of the Brown Hill Junction lodes the latter close to the Mystery lode: in the latter case there were also a number of auriferous cross veins present.

It is probable that much of the so-called "alluvial" gold within this area has been deposited by these vadose waters.

* Bulletin No. 51, p. 19.

B. Detrital Deposits.

(a) *Eluvial Deposits.*

These are due to the weathering *in situ* caused by the action of wind, rain, and changes of temperature at the surface. Such deposits are found in the immediate vicinity of outcrops of lodes and quartz veins.

(b) *Alluvial Deposits.*

True alluvial deposits, *i.e.*, those due to stream action, are not common within this area, being confined to the few narrow water-courses which run down to the valleys on both sides of the Intrusive Greenstone dyke, while, owing to the gentle slope of these and the fact that running water is only found in them after heavy rains, the gold is never very far from its source. Even in these water-courses some of the gold may have been deposited by wind action.

IV.—EVIDENCES OF DYNAMIC ACTION.

The compression and tension to which the earth's crust has been subjected from the earliest times in the effort to accommodate itself to the lessening surface area due to contraction, must have greatly affected rocks of such vast antiquity as those of the Kalgoorlie region. That the area in which the Kalgoorlie auriferous belt is situated has formed a general line of weakness along which these earth-movements found relief is evidenced, not only by the lodes themselves, but also by the number and variety of sheared zones, faults, etc., which are found within the area covered by this report. Some of the schistosity and jointing is probably due to local agencies—for example, it is probable that the Older Greenstones underwent some shearing during their intrusion by the Younger series.

The sheared zones of the lodes and jaspers (or graphitic schists) were evidently the result of pressure in a W.S.W.-E.N.E. direction. In this area these compressive stresses seem to have found relief along four main lines of shearing running in a general N.N.W.-S.S.E. direction; these lines are not continuous, being broken for a considerable distance in some instances; in addition, minor shear lines occur, sometimes roughly parallel to the main lines, sometimes apparently representing cross fractures between two main lines. The general dip of the main lines is to the west at a steep angle.

The westernmost line is represented by the Golden Zone and the westernmost of the Golden Dream lodes; south of the latter there is apparently a big gap, south of which this line is occupied by the series of jaspers and graphitic schists running between the Reward-Mt. Charlotte leases and Williamstown. East of this first

line is a second, occurring along the eastern edge of the main albite-porphyrite dyke, and now represented by the Mystery and Red White and Blue lodes; south of this, this line is occupied by two small barren lodes in the Hidden Secret North, and further south by the Hidden Secret and Hidden Secret South lodes. At this end this line is joined by the third and probably the longest and strongest line, represented by the main jasper running from beyond the northern limits of the map through the Sir John, Ivy, Devon Consols, and other leases to a point south of the Bulong Road. Further south this line is occupied by the band of fuchsite-carbonate quartz rock running through the Hidden Secret leases. At its northern end the fourth line runs towards the third, north of the North Collier; south of this lease it appears to be broken for a short distance and is then occupied by the Westralia United line of lode, running from north of the Kanowna Road nearly to the Bulong Road; then comes the roughly N.-S. formation of the Isabel, Creswick, and A.W.A. United, with its numerous spurs. If the second and third lines continued further to the south they would run into the fourth south of the A.W.A. United.

Those results of dynamic action, other than the sheared zones of the lodes and graphitic schists, may be separated for convenience into:—

(a) The barren N.-S. shear zones, and

(b) The faults.

(a) *The Barren N.-S. Shear Zones.*

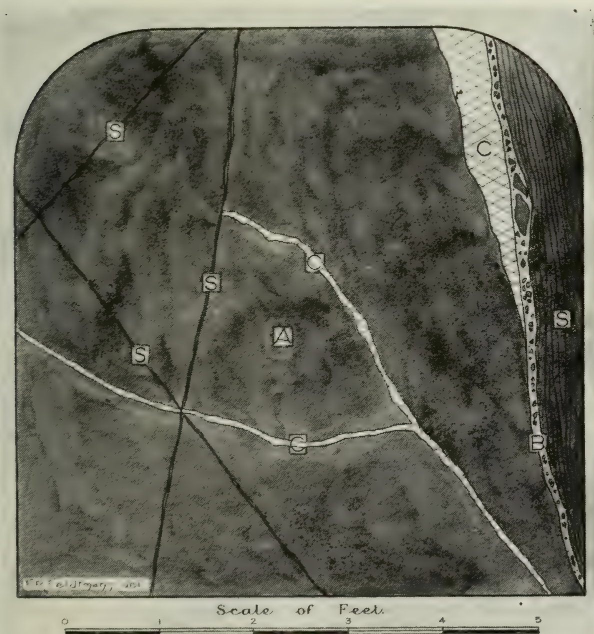
An extensive series of these shear zones is found running through the Hannan's Reward-Mt. Charlotte leases, in quartz-dolerite greenstone. In strike they are practically N.-S., and the usual dip is to the west at a steep angle. In the above-mentioned mine there are two main lines, about 200 feet apart, the westernmost of which may, for convenience, be termed the "Charlotte shear zone"; the easternmost, the "Reward shear zone." A number of subsidiary lines of shearing and faulting run between them, sometimes roughly parallel, sometimes running diagonally from one to the other (*vide* maps and Plate IX.).

The Charlotte shear zone varies in dip from 60 to 80 degrees, but usually dips at about 70 degrees. The Reward shear zone is steeper, being vertical at the lower levels, but dipping to the west at about 70 degrees, or a trifle more, near the surface. Running into the latter near the southern end of G.M.L. 97E are two parallel shear zones, about 120 feet apart, striking about N.W.-S.E. and dipping south-west at from 50 to 60 degrees; whether these resulted from the same stresses as the N.-S. shear zones, or are older formations which were further sheared at the period when the latter were

formed, it is impossible to say owing to the inaccessibility of the deeper levels of the mine, but I am inclined to the former view. In the Cassidy Hill mine, in the angle between N.-S. and the N.W.-S.E. shear zones, the country is much shattered and jointed, and there are a number of small N.-S. fault planes (Plate VIII.). Another well defined N.-S. shear zone occurs in the Lord Nelson G.M.L. 4477E; this dips west at about 75 degrees in the upper levels, but is practically vertical between the 191ft. and the 290ft. levels.

In the oxidised zone these shear zones greatly resemble the schistose lode formations in general appearance, but the N.-S. strike and the fact that they fault the cross quartz veins serve to identify them. Below this zone, examination shows an absence of the marked metasomatism characteristic of the true lode-formations, the shear zones being represented by a band of schistose and sometimes brecciated rock, associated with a few white carbonate veins (Fig. 19).

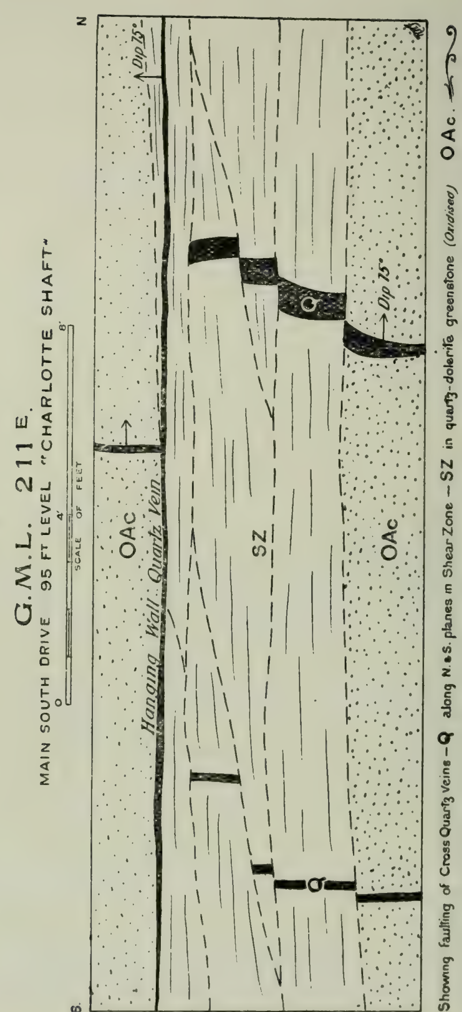
Fig. 19.



LORD NELSON G.M.L. 4477E — Main Shaft, 191 Ft. Level. Face of N. Drive showing Shear Zone in quartz-dolerite amphibolite A, with brecciated zone B, planes of shearing S, and carbonate veins C.

The evidence as to the relative movement of the rocks along these shear zones is unsatisfactory. As seen in plan (Figs. 20-25)

Fig. 20.



the cross veins have been thrown to the north. going west; if the movement was vertical, then the downthrow was on the eastern side. One instance of movement in the contrary direction was seen in the north drive on the graphitic schist at the 290ft. level from the Charlotte shaft (Fig. 22), where a quartz vein was apparently thrown to the north going east—this looks like local block faulting. Striæ were visible on the shear planes only in a few instances; some appeared to pitch diagonally to the north, others were horizontal; as there may have been subsequent local movements this evidence is unsatisfactory.

Fig. 21.

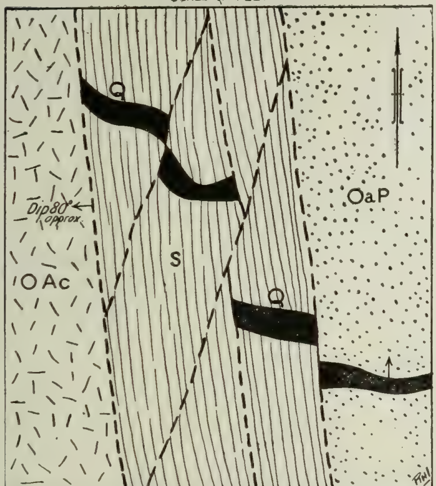
G.M.L. 211E.

5TH DRIVE OFF MAIN E. CROSSCUT 95 FT LEVEL

"CHARLOTTE SHAFT"

0 4′

SCALE OF FEET



Sketch Plan showing faulting of cross quartz vein - Q (which cuts planes of schistosity) by planes of N-S shear zone — S at junction of quartz-dolerite = greenstone (ankerised) OAc and probable albite-porphyrite (ankerised) OaP

Fig. 22.

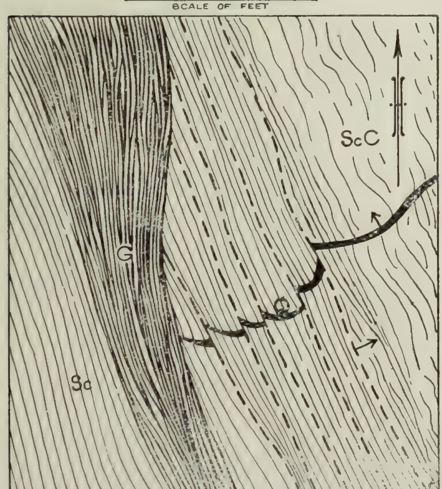
G.M.L. 211E.

NTH DRIVE OFF MAIN E CROSSCUT 290 FT LEVEL.

"CHARLOTTE SHAFT"

0 4′

SCALE OF FEET



Sketch Plan showing faulting of cross quartz vein - Q in opposite direction to that of figs 20 & 21 ScC - sheared carbonate quartz sericite rock G - graphitic schist
Sc gray carbonate - quartz - sericite schist

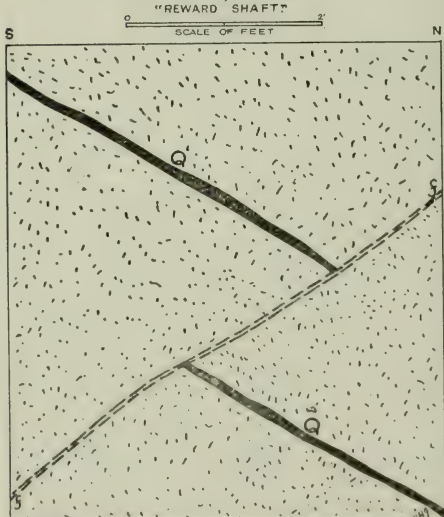
Fig. 23.

G. M. L. 211 E.
55 FT LEVEL, MAIN S DRIVE
"CHARLOTTE SHAFT."

Section looking W. showing cross quartz veins - Q turning along "head" H but cut by fault §.

Fig. 24.

G. M. L. 97 E.
80 FT LEVEL, N. DRIVE.
"REWARD SHAFT."

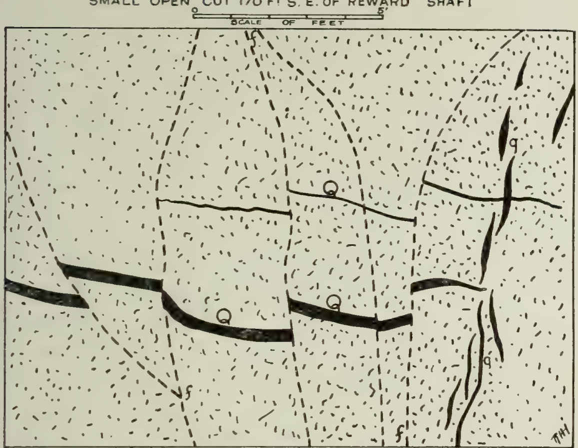


Section looking W. showing overthrust faulting of cross quartz vein Q by E W fault plane.

Fig. 25.

G.M.L. 97E.

SMALL OPEN CUT 170 FT S. E. OF "REWARD SHAFT"



Sketch section looking N.W. showing faulting of flat cross quartz veins — Q by vertical faultplanes f also vertical series of quartz lenses q.

It is highly probable that the compressive stresses which caused the N.-S. shear zones caused further shearing along the lode channels, with faulting of the adjacent cross veins, such as can be seen in the Hidden Secret and other mines.

(b) *Faults.*

The most important series of faults within this area is one striking S.S.W.-N.N.E. and best represented in the Golden Zone group of leases.* The faults of this series are either vertical or dip steeply to the north, and throw the lodes to the E.N.E. going north; the horizontal component of the movement is greatest at the surface, where it varies usually from 65 to 120 feet, but being only five feet in the case of a small subsidiary fault near one of the main ones. The movement in most instances appears to die out at a depth varying probably between 300 and 700 feet from the surface.

The fault in the Mystery mine affecting both the lode and the albite-porphyrite dyke belongs to this series, which appears to have resulted from pressure from a S.S.W. direction.

Examples of another series of faults striking nearly E.-W. and dipping south at about 30° were seen by the writer in G.M.L. 97E, where they fault the cross veins (Fig. 24), in the Cassidy Hill lease—where the movement, in one instance, appeared to be to the east, going north—and in the former Eaglehawk United G.M.L.

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* Bulletin No. 51, pp. 23-4 and Plate III.

3770E. These appear to be overthrust faults resulting from pressure from the south.

A fault with similar strike, but with generally vertical dip occurs in the Mt. Ferrum Consols G.M.L. 4230E, where it throws the lodes to the west, going north (Plate X.); at the 199ft. level and on the eastern side of the drive, this fault had a southerly dip of about 65°.

In the Fair Play mine, at the 107ft. level (*vide* Fig. 16), two fault planes about four feet apart, striking N.N.W.-S.S.E. and dipping E.N.E. at about 65°, throw the lode about 4 feet to the west, going north; other similar faults apparently occur on this mine.

Other minor faults, possibly due to local movements, were seen in G.M.L. 4499E, Williamstown, where a N.-S. fault dipping at from 45° to 60° to the east faults a quartz vein about 6 inches to the north going east.

In the Creswick mine, in the fine-grained greenstone at its junction with the quartz-dolerite greenstone, some small faults were observed striking about N.W.-S.E. and dipping N.E.

V.—THE PROCESSES OF ALTERATION.

In a report of this nature a detailed discussion of the various processes by which alteration of the original rocks has been effected is impossible. A brief account, however, may be given of the main types or degrees of alteration which may be classified as follows into those involved in the formation of—

(a) The amphibolites.
(b) The greenstones.
(c) The bleached greenstones.
(d) The lode formations.
(e) The graphitic schists.

(a) In the main, dynamic action in the form of intense pressure is the agent most chiefly concerned in the formation of the amphibolites, resulting in the formation of uralitic hornblende and saussurite (epidote, zoisite, etc.) at the expense of the pyroxenes and plagioclase felspars of the original rocks. A certain amount of contact action, however, was apparently the cause of certain features such as the spheroidal structure in some of the fine-grained amphibolites and greenstones in the vicinity of the Younger Greenstones.

(b) The processes involved in the formation of the greenstones are somewhat obscure, but it is probable that it is mainly incipient vein-alteration resulting from the widespread action of the highly carbonated, potash-bearing solutions to which the formation of the lodes is due. Whether this alteration was effected on the original rocks or on the amphibolites is difficult of proof, but owing to the

long-continued pressure to which the rocks of this particular locality must have been subjected prior to the introduction of the auriferous solutions, I am inclined to think that uralitisation of the greater portion of these rocks, at any rate, must have preceded the carbonation.

Thomson,* discussing the relationship of the "porphyries" (albite-porphyrites) and porphyrites to the quartz-dolerite series, lays stress on the importance of the part played by albitisation in the formation of the greenstones, and considers that†

"Albitization and the concomitant processes that gave rise to the greenstones constitutes the incipient vein-alteration, extreme carbonation and sericitisation with minor silification, the final vein-alteration."

On this point the evidence afforded by analyses is contradictory. Analyses of some of the greenstones show an even smaller percentage of soda than do those of the amphibolites, although their potash content is slightly higher; others, however, show an increased soda percentage up to as much as double that of the amphibolites—these last greenstones are in fairly close proximity to an albite-porphyrite dyke—the latter is carbonated in places and the carbonated variety shows a marked decrease in soda (Table I., No. 3), which may account for the increase in some of the greenstones. A complete examination of the Golden Mile is necessary before the question of albitisation can be finally settled. It certainly looks as though a certain amount had taken place in the vicinity of and resulting from the albite-porphyrite intrusions; on the other hand, saussuritisation, with the production of secondary albite, is characteristic of the amphibolites, and most of the albite in the North End greenstones at any rate is probably the result of this. Thomson states‡ that the rocks from which the greenstones were derived were, on the whole, more siliceous than those now represented by the amphibolites. Whatever is the case on The Mile, analyses show that this is not so at the North End.

(c) The bleaching of some of the greenstones marks a further stage in the process of vein-alteration, marked as a rule by a slightly increased percentage of CO_2, and a considerable increase of potash and sulphur with the resultant formation of sericite and pyrite at the expense of the former ferro-magnesians, and possibly the replacement of some of the leucoxene by pyrite; a fair percentage of boron is also present at times.

(d) The lode formations represent the final degree of alteration with, in the case of the quartzose lodes, marked increase of silica in the central portion of the lode; in the case of the Fair Play and Hidden Secret shoots, the reverse seems to have taken place. Most, if not all, of the increased silica in the quartzose

* *Loc. cit.*, p. 663, *et seq.* † *Loc. cit.*, p. 668. ‡ *Loc. cit.*, p. 673.

lodes is probably due to concentration of secondary silica resulting from the alteration of the ferro-magnesians. In the case of the exceptions mentioned above, much of the secondary silica has probably been concentrated in the cross quartz veins. The most important feature of this final stage of alteration was, of course, the increased amount of gold, silver, and tellurium.

(e) The changes involved in the formation of the graphitic schists have already been discussed, and need not be further described.

VI. THE RELATIVE AGE AND RELATIONSHIP OF THE ROCKS.

(a) *The Older and Younger Greenstones.*

Putting aside for the present the discussion of a possible magmatic relationship between the rocks of these two series, we will consider the question of their relative age. On this point the evidence afforded by this area is very meagre, the exposures of apparent junctions between the rocks of the two series being, as already stated, exceedingly few and confined to the zone of oxidation. Thomson's remarks as to the possibility of the fine-grained series being regarded as chilled margins of the coarser grained series have been quoted on a previous page, and the evidence afforded by the maps as to the extent of the former series confirms his views. Moreover, the apparent contact metamorphism of some of the fine-grained amphibolites near their junction with the intrusive series, and the occurrence of quartz-dolerite amphibolite on the dump of the water-shaft on M.L. 105E, well inside the main mass of the fine-grained greenstones—in all probability a dyke intrusive into the latter—point to the fact that the original quartz-dolerite and allied rocks were later than, and intrusive into, the lavas from which the fine-grained series were derived.

(b) *The Members of the Younger Greenstone Series.*

The evidence on this question is by no means as complete as could be desired, but what there is appears to be in favour of the view that the members of this series were intruded rather as one dyke in which differentiation had taken place prior to its intrusion and solidification, than as a series of dykes, of different composition, derived from the same magma but with an interval of time between each. In general, the rocks of the various groups appear to merge into each other—direct field evidence on this point being afforded by some of the mine workings; moreover, microscopic examination points to the presence of intermediate varieties, although, the rocks being somewhat altered, this evidence is not conclusive; in no instances were the rocks of any one type seen to occur as dykes in

those of another type. At other mining centres as, for instance, Bulong, gabbros—and amphibolites derived therefrom—are found to be intimately associated with serpentines which the determination of typical specimens shows to have been derived from augite-peridotites; the two rocks can frequently be seen on the one hill apparently merging into each other, and in no instance did either rock appear to occur as a dyke in the other, whereas dykes of hornblende-porphyrite were frequently seen intruding both. Unfortunately it has not yet been possible to microscopically examine a number of rocks collected from this locality by the writer, which might throw a good deal of light on this matter. On the whole, the evidence cannot be regarded as conclusive, although what there is is distinctly in favour of the intrusion of the Younger Greenstones as one dyke.

(c) *The Younger Greenstones and the Porphyrites.*

With the exception of the previously mentioned specimen of hornblende-porphyrite collected by Mr. Campbell from a shaft north of the Hyman North, and evidently from a dyke in the quartz-dolerite greenstones, no evidence is afforded by the North End as to the relative age of the hornblende-quartz-porphyrites and the Younger Greenstones. At Bulong, however, hornblende-quartz-porphyrites exactly similar to those of Kalgoorlie are found as dykes in the gabbros, amphibolites, and serpentines corresponding to the Younger Greenstones of Kalgoorlie, and there is no reason to suppose that the corresponding rocks of the two localities are of a different age. There seems, then, to be little doubt that the hornblende-porphyrites are later than the Younger Greenstones.

As regards the albite-porphyrites, the evidence is conclusive, for they have, in several instances, been seen *in situ* as dykes in the Younger Greenstones.

(d) *The Hornblende-Quartz-Porphyrites and the Albite-Porphyrites.*

The relationship between these rocks has already been considered to some extent. Here, also, the evidence is inconclusive, but the resemblance of many local varieties of the hornblende-porphyrites at Bulong to the albite-porphyrites, and the occurrence in the Mystery and Hyman leases, at the North End, of varieties of the albite-porphyrites with well developed hornblende phenocrysts, point to a close relationship between the two rocks, and it seems highly probable that the albite-porphyrites are apophyses from the main body of porphyrite occurring to the west of the Kalgoorlie townsite.

(e) *The possible Magmatic Relationship between the various Igneous Rocks of the North End.*

As we have seen, on the balance of evidence it would appear that the Younger Greenstones were later than, and intrusive into, the Older series; also, that the porphyrites were intrusive into the former series. There remains the question of their possible derivation from the same magma. Any discussion on this point must necessarily be largely speculative.

Dr. Thomson* has suggested the possible magmatic relationship of the igneous rocks of Kalgoorlie as members of a spilitic suite, and compares analyses of the quartz-dolerite amphibolite and the albite-porphyrite with those of similarly associated rocks of Great Britain. On the other hand, later analyses of Kalgoorlie amphibolites, including those of the North End, show, on the average, a much lower percentage of soda than is shown in the analysis quoted by Thomson, so that, in the absence of further evidence to the contrary, the main group of these rocks cannot be considered as other than derivatives of normal quartz-dolerites.

As regards the fine-grained series, the only analysis made of a fine-grained amphibolite shows a comparatively high soda percentage, but the potash also is exceptionally high, and in the two analyses of undoubted fine-grained greenstones the soda is certainly not above the normal for basaltic rocks.

But, on the other hand, although there is little evidence for the inclusion of these two series in a spilite suite, the analyses of the fine-grained rocks show a marked similarity to those of the less basic members of the Younger Greenstones and suggest the possibility of a close relationship between them, although for the present this cannot be considered as anything more than probable.

With regard to the porphyrites, their frequent association with gabbros or dolerites and their derivatives, as well as serpentines, in other mining centres, certainly suggests that the former may be a later differentiation from the same magma. The fact that the Ora Banda porphyrite approaches so nearly to the greenstones in composition† certainly seems to favour this view. Harker,‡ describing the Tertiary igneous rocks of Skye, which he regards as "'probable products of 'differentiation' from one common stock, viz.: a large body of fluid rock-magma initially of uniform composition and occupying an intercrustal reservoir at some unknown but very considerable distance beneath the surface.''§
shows that—

''igneous activity has manifested itself successively under three different phases, the Volcanic, the Plutonic, and the 'Dyke Phase' or. . . . 'the Phase of Minor Intrusions.' ''

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* *Loc. cit*, pp. 663, *et seq.*
† "The Mining Geology of Ora Banda," G.S.W.A. Bulletin No. 54
‡ "The Tertiary Igneous Rocks of Skye," Mem. Geol. Surv., Great Britain, 1904.
§ *Loc. cit.*, p. 416.

If the derivation of the Kalgoorlie rocks from one parent magma be assumed, the order of emission shows a fairly strong similarity to the above phases of igneous activity, for we have first the volcanic lavas—the presence of tuffs has not been satisfactorily proved—from which the Older Greenstones were derived; secondly the dolerites, gabbros and more basic members of the Younger Greenstones, which on the whole may be considered plutonic in character, although in Kalgoorlie itself remains of a former doleritic structure are more common than those of a former gabbroid; thirdly, there are the porphyrites, which do not agree so closely with Harker's third phase, excepting in the case of the albite-porphyrites—and some hornblende-quartz-porphyrites at Bulong—but are rather intermediate between the second and third phases. In addition Harker emphasises the fact that—

"the distinct foci at which activity was from time to time localised were also the principal centres of magmatic differentiation."*

In this connection the association of gabbros or dolerites, peridotites—or their derivatives—and porphyrites at Bulong, Ora Banda, and other gold-mining centres, in addition to their occurrence at Kalgoorlie is, at least, significant.

On the whole, then, although there can be no definite proof, it must be admitted that the probability of the derivation of the Kalgoorlie igneous rocks from one parent magma is fairly strong.

VII.—SUMMARY AND CONCLUSIONS.

The Geological History of the North End.—Summarising the results of the foregoing chapters it is possible to form some idea of the probable sequence of events in the geological history of the North End. This history is necessarily incomplete, and at present it is not possible to place some of the results of dynamic action in their proper chronological order. The correct position of the probable sediments of the Phoenix brick pits is also uncertain, but if they belong to the same series as the sheared conglomerates of Binduli, etc., they were probably formed at a later date than the intrusion of the porphyrites at any rate. But owing to the uncertainty of their position and the fact that they are of little importance within this area, they are not included in the following history.

In the first place, we must regard the Kalgoorlie region as a portion of the earth's crust attempting to accommodate itself to a lessening horizontal area due to the contraction of the earth as a whole. This resulted in a long continued period of pressure during which the rocks were sheared, crushed and fractured in places. The fissures so formed would naturally form paths for intrusions and

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* *Loc. cit.*, p. 419.

ore-bearing solutions emitted during the intervening minor periods of relaxation.

It would appear that the earliest rocks of which we have evidence were lavas of basaltic composition probably exuded from fissures during a period of relaxation. We can form no opinion as to the original extent and depth of these rocks or of the period of time covered by their effusion, while as to what rocks constituted the surface on which these lavas were laid down there is no evidence. It is probable that these Older Greenstones more nearly represent the average composition of the parent magma than any of the later emissions from that magma, although differentiation may have already taken place to some extent.

At a later date the quartz-gabbros or quartz-dolerites and the other and more basic members of the Younger Greenstones intruded the lavas along a line of weakness having a general N.N.W.-S.S.E. strike and resulting from pressure at right angles to that direction. The Younger Greenstone intrusion appears to have produced a certain amount of contact metamorphism in the older series; this is evident in places along the eastern edge of the former; it is improbable, however, that any absorption of the older rocks took place owing to the similarity in composition of the two series. Both rocks may have been sheared to some extent round their margins.

Subsequent pressure from the same W.S.W.-E.N.E. direction produced the lines of weakness in the Younger Greenstones along which the dykes of albite-porphyrite were intruded—probably as apophyses from the main body of porphyrite.

A further period of intense pressure from the same direction shortly after the intrusion of the porphyrites, resulted in the shearing of the Older Greenstones, Younger Greenstones and the albite-porphyrites along the four main lines mentioned in Chapter IV. with numerous minor fissures, including those at right angles and complementary to the main shear lines.

At a somewhat later period further pressure, this time from the North, resulted in overthrust faulting along E.W. lines with a shallow northerly dip.

During the long continued period of compression the Greenstone rocks were uralitised and saussuritised.

Following on the last mentioned period of pressure from the north, highly active solutions and vapours, containing boron, sulphur and carbon compounds—the latter probably a hydrocarbon—and perhaps some potash, forced their way along some of the N.N.W.-S.S.E. shear zones to form the graphitic schists. Closely following on these solutions came others containing enormous quantities of carbonic acid together with sulphur and potassium—probably combined as potassium sulphide—and also gold, silver and tellurium;

these resulted in the formation of the lodes and the auriferous cross quartz veins. These solutions would produce the greatest metasomatic alteration along the main shear lines with gradually diminishing alteration away from them. Bleaching, owing to the breaking up of the ferro-magnesians, with the formation of pyrite, etc., would take place to a greater or less extent in the immediate vicinity of the channels along which the solutions found their way, with the resultant formation of the bleached greenstones and the fuchsite-carbonate-quartz rocks; while the greenstones represent a lesser degree of alteration away from those channels. Carbonation probably continued over a long period, for carbonate veins are found associated with the later shear zones. It is possible, however, that these veins are due to the action of circulating vadose waters.

Earth movements continued to take place long after the formation of the ore deposits, one of the most important being the result of pressure, probably from the west, causing shearing along N.-S. lines with the formation of the shear zones of the Reward-Mt. Charlotte and the Lord Nelson and probably the re-opening of fissures along the lode channels.

Another important series of movements resulting from pressure from the S.S.W. faulted the Golden Zone and Mystery lodes, while a series of overthrust faults striking E.-W. was the result of pressure, this time from the south, the effects of this last being evident in the faulting of cross quartz veins in the Hannan's Hill, Cassidy Hill, and Eaglehawk United leases.

These later movements are not given in chronological order, there being no evidence as to their relative age.

It must be remembered that the above history is largely hypothetical, but it is that which seems most probable to the writer on the available evidence.

The Relative Economic Importance of the Rocks.—Turning to the question of the relative economic importance of the rocks, the most important point to be remembered is that, in this area, the payable lode-formations are invariably associated with the greenstones—never with the amphibolites. At the North End the quartz-dolerite and dolerite greenstones have proved of the greatest economic importance, the fine-grained greenstones ranking next; in the latter rocks the lodes are, on the average, poorer and more patchy. The albite-porphyrites have not, so far, proved to contain payable lodes—although lodes in which rich patches occur are found at the junction of these rocks with the Younger Greenstones, but the fact that the auriferous solutions have in all probability been after-emanations from the magma from which these rocks and the hornblende-porphyrites were derived makes them of very great significance so far as the occurrence of payable lodes in other districts is concerned.

Regarding the occurrence of lode formations in the fine-grained greenstones and calc-schists—as already stated, Dr. Maclaren regards these rocks as being normally barren, and considers that the exceptionally rich ore found in them—such as that of the Oroya-Brown Hill shoot and the Eclipse lode, in the more southerly portion of the field—has travelled in solution from the quartz-dolerite to be deposited in the calc-schist along the main shear lines. Apparently, then, Dr. Maclaren regards the auriferous solutions as having a close genetic connection with the quartz-dolerite, and, therefore, that the occurrence of payable lodes in the Older Greenstones is abnormal and due to special conditions. In dealing with the fine-grained greenstones, the present writer mentioned the comparative proximity of the lodes in these rocks to the boundary of the Younger Greenstones, and, further that most are connected with the narrow and persistent formation which follows that boundary very closely; thus apparently confirming Dr. Maclaren's views. There is, however, another possible explanation, namely, that the relative proximity of these rocks to the source of the auriferous solutions, together with the position of the main lines of weakness along which these solutions travelled, determined the relative economic value of these rocks. The area now occupied by the Younger Greenstone dyke has evidently been one of weakness, most affected during the long period of earth-movements, with the result that the main lines of shearing are in these rocks, the Older Greenstones being affected to a minor degree near their junction with the Younger rocks; moreover, the junction of the two series would be a potential line of weakness. As we have seen, the albite-porphyrites have been intruded along some of the older lines of weakness in the Younger Greenstones, and if the auriferous solutions were genetically connected with the former rocks, it is most probable that they would travel so far as possible along the same channels, or along the major shear lines which had been formed near the former after the intrusion of the albite-porphyrites. The metasomatic action, with the deposition of gold, would be greatest along the main channels and least along the minor shear lines farthest away from the main lines; so that in the shear zones in those rocks—now represented by quartz-dolerite amphibolites, fine-grained amphibolites and other amphibolitic rocks—where the solutions have had least effect, the gold content would be negligible, while in the fine-grained greenstones and calc-schists the lodes would be comparatively poor and patchy. Moreover, as regards the relative richness of the North End and the Golden Mile, it is probable that the same explanation holds good, namely, that the latter locality has been more highly sheared and was more closely connected with the source of the gold-bearing solutions.

Additional evidence against the theory that the Younger Greenstones were themselves the original source of the gold, the latter being presumably held in combination by the ferro-magnesian

minerals*—the splitting up of these permitting the dissolving of the gold with subsequent deposition in the lode formations—is that in other districts, such as the Ularring,† where great numbers of auriferous quartz reefs occur, the country rock is amphibolite, derived from a dolerite or gabbro apparently of the Younger Greenstone series, and even in the sheared zones in the immediate vicinity of the reefs, the hornblende has not been appreciably chloritised; so that, in that district, at any rate, this theory does not hold good. Whether such was the case at Kalgoorlie no direct proof is at present possible, but the occurrences of the Ularring district certainly afford circumstantial evidence against this theory.

VIII.—THE MINES.

Milanese G.M.L. 4293E (Golden Dream G.M. Co., N.L.).

The northern portion of this lease was dealt with in the previous report (Bulletin No. 51, pp. 34-5), and only the southern portion of the lease, formerly held as G.M.Ls. 4219E, 4073E, 4012E, Golden Dream, and at an earlier date as G.M.L. 1620E, Elsie Conliffe, will be described here. All these leases covered the same ground, situated in the low-lying area south of the Devon Consols Consolidated G.M.L. 1121E and the Transcontinental Railway line.

The ground is largely covered by superficial deposits, and oxidation of the underlying rocks has extended for a considerable depth, but judging by its exposure in the Transcontinental Railway cutting, the greater portion of the ground is occupied by the dyke of albite-porphyrite which runs south from the Lone Hand and Mystery mines. In this lease the dyke appears to split going south, but the evidence on this point is very unsatisfactory. The most eastern portion of the lease is in dolerite greenstone.

The two eastern lodes occurring in the northern portion of the lease have been met with in the workings from a shaft about 125 feet in depth, near the western boundary of this portion of the lease, but payable values were not obtained. This shaft is connected by a cross-cut, at a depth of 105 feet, with an incline shaft about 230 feet to the north-east, put down on a large cross quartz vein dipping to the north at about 70°. This quartz vein is exposed in a costeen running between the two shafts, and is there seen to be faulted by a small N.W.-S.E. striking fault. Other cross quartz veins have been worked on this portion of the lease. Several small shafts, now inaccessible, have been put down on this portion of the lease, but nothing of importance appears to have been encountered. On the other hand, good values have been obtained in other leases along the same line from formations on the eastern side of the albite-porphyrite dyke, for instance, in the Mystery, Little Wonder, and

* C. G Gibson, *loc. cit.*, p. 29.
† G.S.W.A. Bulletin No. 60, p. 153.

more recently in Mr. H. Raven's Red White and Blue G.M.L. 1228E, so that it would be worth while to do further prospecting along that line.

Apparently the only returns from this portion of the Milanese were for G.M.L. 4073E, namely, 41 tons for a total of eight fine ounces.

GORDON G.M.L. 4539E.

This lease is situated to the east of the Broad Arrow Road, immediately south of the Kanowna Railway line and on the north-west slope of Mt. Charlotte. It was until recently held as G.M.L. 4412E of the same name (Cunard G.M. Co., N.L.), and prior to that the greater part of the ground was held as G.M.L. 4128E, Excelsior, and at an earlier date as parts of G.M.Ls. 1100E, Chandos, and 879E, Richmond.

A band of quartz-dolerite greenstone, probably averaging three chains in width, runs through the middle of the lease, the south-western portion of which is in quartz-dolerite amphibolite, and the eastern portion likewise in amphibolite, which is here more gabbroid in appearance.

The main shaft is situated near the centre of the lease in the greenstone belt. I was unable to ascertain the exact depth of this shaft, the lower levels, which were in sulphides, being inaccessible. A good deal of work had been done at and above the 95ft. level, on a number of the E.N.E.-W.S.W.-striking cross quartz veins. In this mine these veins dip north at about 60 degrees, or slightly steeper. A few of the flatter cross veins occur, but in this mine the steeper series were said to carry better values. I could see no definite lode formation, but several shear planes, following the usual strike of the country and dipping W.S.W. at angles between 50 and 60 degrees, were observed; the relationship between these and the cross quartz veins could not be distinguished.

Both veins and intervening country have been stoped out to a considerable extent, and there has evidently been a fair amount of secondary impregnation in the oxidised zone.

A fair amount of work has been done on the "alluvial" ground at the northern end of the lease.

As there does not appear to be any well-defined lode on this mine, its future prospects depend on the cross quartz veins in the narrow belt of greenstone. Judging by the work that has been done so far, these do not seem to be sufficiently close to enable them, together with the intervening country, to be treated on a large scale, particularly as the limit of oxidation is probably not far from the surface at the southern end of the lease; and the mining of the cross

veins by themselves is more suited to small parties than a large company or syndicate.

At the time of my visit the treatment plant consisted of a Huntingdon mill of local manufacture.

Returns for this and former leases are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
Gordon, 4412E	5,138·25	557·82	0·11
Excelsior, 4128E	546·00	109·13	0·20
Quartz Claim, 234E	96·00	16·51*	0·17*
Totals	5,790·25	683·46	0·12

* Not reduced to fine ozs.

Gordon South G.M.L. 4446E (now voided).

This lease was situated south-west of and adjoining the Gordon. The country rock of the area covered by this lease is quartz-dolerite amphibolite. The northern portion of the ground is covered by superficial deposits, probably of no great depth. The unoxidised rock is close to the surface in the southern portion of the ground. One shaft had been put down near the centre of the ground of which no particulars are available; the rock on the dump, however, is amphibolite of the Warden's residence type. There are no returns for this area, and there do not appear to be any reasonable prospects of anything payable being found, though a few cross veins may possibly occur.

Prince Foote G.M.L. 4425E (voided).

The ground covered by this lease formed part of the earlier St. Mungo G.M.L. 1292E, later the Hannan's Britannia. It is situated partly in the angle formed by the Kanowna and Boulder Railway lines, close to their junction, and partly north of the former railway.

In the angle between the two lines there is a small laterite-capped rise, under which a fair amount of work has been done, and there are numerous shallow shafts on the ground. The country rock is nowhere exposed, but the western portion of the lease is possibly in the southern extension of the dolerite greenstone exposed in the Mullingar quarry; the extreme eastern portion is most probably in quartz-dolerite amphibolite. Fragments of a jasper formation were visible on an old dump beyond the western boundary of the lease and close to the Kanowna Railway line.

The gold obtained from under the laterite cap has probably been formed by secondary impregnation after being leached out of cross quartz veins. No lode formation has apparently been found in this ground.

The only returns are for G.M.L. 1292E, from which 374.5 tons of ore were treated for a return of 257.86 fine ozs.—an average of 0.69 fine ozs. per ton.

Enterprise G.M.L. 4509E.

This lease lies to the east of the Gordon and south-west of the Milanese, on the northern slope of Mt. Charlotte, the southern portion of the lease covering the northern portion of the Reservoir Water Reserve. This lease and the adjoining Enterprise South are held by the Adelaide Enterprise Prospecting Syndicate, N.L., being granted conditional to there being no mining on the Reserve within 200 feet of the walls or floor of the Reservoir. The ground was formerly held as G.M.L. 4153E, £ s. d., and previously as part of G.M.L. 879E, Richmond.

The small area of gabbroid amphibolite occurring on the east of the Gordon probably runs diagonally across this lease, the north-eastern and south-western portions being in quartz-dolerite greenstone.

But little work has been done on this lease and none of the shafts were accessible. There are no signs of any lode formations in this ground, but cross quartz veins should occur.

Returns for this ground are for G.M.L. 4153E from which five tons were treated for a return of .36 fine oz., an average of 0.07 fine ozs. per ton.

Enterprise South G.M.L. 4530E (Fig. 26).

This lease is situated to the south of and adjoining the previous one and was formerly the northern portion of G.M.L. 212E, Mt. Charlotte, part of which was afterwards resumed as part of W.R. 9892.

With the exception of the extreme western portion, the lease is entirely in quartz-dolerite greenstone.

At the time of my visit work was being carried on at the south-eastern corner of the lease from the main shaft, which was 145 feet in depth, on a number of cross quartz veins similar to those in G.M.L. 211E further south. The country between them was impregnated to some extent and was being mined together with the quartz veins. There were no signs of any lode formation; and although the cross quartz veins are fairly numerous, and oxidation appears to have reached a considerable depth in the eastern portion

of the lease, the future prospects are not very great, owing to the necessarily restricted mining.

Official returns up to the end of 1914 show a total of 1,901 tons treated for a return of 407.43 fine ounces, an average of 0.21 fine ounce per ton.

Fig. 26.

Photo: F. R. Feldtmann. Neg. F186.

Mt. Charlotte Reservoir and Enterprise S. Main Shaft from S.E.

There was a Huntingdon mill worked by a suction gas engine of $22\frac{1}{2}$ h.p. on the mine.

BRILLIANT G.M.L. 1653E. This lease, together with G.M.Ls. 97E, 160E, 211E, 213E, and 4529E, is held by the Hannan's Reward, Ltd., formerly the Hannan's Reward and Mt. Charlotte, Ltd. This lease is the northernmost of the group, and is situated south of and adjoining the Milanese and east of the Enterprise.

The two branches of the big albite-porphyrite dyke occurring on the Milanese pass through this lease, the western portion of which is in quartz-dolerite-greenstone, the extreme eastern, and probably that portion between the two branches of the albite-porphyrite, in dolerite-greenstone.

There are five comparatively shallow shafts on this lease, the middle one, Romaine's shaft, near the northern boundary, having a depth of 130 feet. On the dump of this shaft small crystals of axinite,* a borosilicate of aluminium and calcium, were found by Dr. Thomson in fragments of a quartz vein. This is the only recorded occurrence of this mineral at Kalgoorlie. A search by the present writer failed to reveal further specimens. Specimens of the albite-porphyrite were common on the dump.

The northerly continuation of a jasper outcropping on G.M.L. 213E runs through this lease.

With the exception of a shallow shaft north-east of Romaine's shaft, no work has been done near the eastern branch of the albite porphyrite. As stated when dealing with the Milanese lease, rich patches have been found on the eastern side of this dyke, and it might be advisable to do further prospecting here.

Returns for the leases held by the Hannan's Reward, Ltd., are given later.

MT. CHARLOTTE G.M.L. 213E. This lease is situated south of and adjoining the last, and east of Mt. Charlotte.

The western branch of the albite-porphyrite dyke probably runs through this lease slightly to the east of the middle, while the eastern branch runs close to the north-east corner. The western half of the lease is in quartz-dolerite greenstone, in which several cross quartz veins have been worked near the southern corner.

A jasper formation, apparently on the eastern side of the western branch of albite-porphyrite outcrops on the lease, Clay's shaft (v.d. 104 feet) having been sunk on it. About 460 feet of cross-cutting has been done to the west of this shaft at the 43ft. level, apparently without results.

In the north-eastern portion of the lease some alluvial work has been done along a watercourse which starts near the Kanowna Road.

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* G.S.W.A. Bull. 42, p. 134.

G.M.L. 4529E. This is another of the leases held by the Hannan's Reward, Ltd. It, together with G.M.L. 4530E, was formerly held as G.M.L. 212E, Mt. Charlotte. This lease lies to the south of and adjoining G.M.Ls. 213E, 4530E, and former G.M.L. 4446E.

The western half of the lease is in quartz-dolerite amphibolite, and the greater portion of the western half in the corresponding greenstone. The northern extension of the graphitic schist formation, and the fuchsite-carbonate-quartz rock cut in the east crosscut at the 290ft. level from the Charlotte shaft on G.M.L. 211E, probably occurs in the easternmost portion of the lease. A prominent hill at the south-east corner is covered by dense, highly ferruginous laterite.

Much of the eastern portion of the lease is now covered by slimes dumps, and apparently has not been tested. What is probably the northerly continuation of the "Charlotte" shear zone has been worked to a depth of 80 feet in a shaft about 100 feet south of the south-west corner of G.M.L. 213E, low-grade ore being obtained therefrom, evidently due to secondary impregnation from cross quartz leaders; several of the latter have been worked on the south-west slope of Mt. Charlotte.

A good deal of dryblowing has been done on this lease in the lower-lying ground.

From a point a little to the south of the southern corner of the Reservoir fence a tunnel has been driven into the mount in a northerly direction to a point under the Reservoir; nothing of value was disclosed by this tunnel.

It is unlikely that anything of value will be found in the western portion of the lease, but further prospecting in the area now covered by the slimes dumps would probably disclose other cross quartz leaders which might prove to be payable.

MT. CHARLOTTE G.M.L. 211E. This lease lies to the south of and adjoining the previously described lease.

As in the preceding lease, the western half of this lease is in quartz-dolerite amphibolite, an outcrop of the type rock occurring on the northern boundary at the back of the Warden's residence; west of this the amphibolite is somewhat more gabbroid in appearance.

Most of the eastern half of the lease is in quartz-dolerite greenstone, but on the eastern side of the last-named rock is a dyke of albite-porphyrite, sheared and carbonated in places; east of this, again, is a band of graphitic schist, while still further to the east are areas of fuchsite-carbonate-quartz rock and talc-mesitite rock (*vide* Plates III. and XI.). These rocks were met with in the pre-

viously mentioned east crosscut at the 290ft. level, and were described in detail when dealing with the graphitic schists.

The "Charlotte" or western shear zone, mentioned in the chapter on the Evidences of Dynamic Action, runs right through the leases, passing about 25 feet east of the main shaft at the surface. It can be observed in the huge open-cut near the southern boundary of the lease. In this lease the dip varies between 60 and 70 degrees. Between 180 and 250 feet east of this shear zone is the eastern or "Reward" shear zone, which probably runs into the previously mentioned albite-porphyrite dyke.

A great number of cross quartz veins of the steeper series occur on this lease; they vary from about six inches to a fraction of an inch in thickness, and as a rule carry fair values, the gold in them being fairly coarse. They are undoubtedly the original source of most, if not all, of the gold obtained from this lease, whether from the impregnated country between these veins or the alluvial gold in the lower-lying ground. In the oxidised zone these leaders are easily worked, and, in this mine, being only a few feet apart, the country can in places be profitably taken out *en masse,* as may be judged by the size of the open-cut (Figs. 27 and 28). But few of the flatter-dipping cross veins occur on this lease, though particularly common in G.M.L. 97E to the south.

The main shaft, which has a vertical depth of 496 feet, is situated about 520 feet south-west of the north-east corner of the lease, and levels have been driven at depths of 95, 190, 290, 388, and 488 feet. Crosscuts were driven east from the three upper levels, cutting the graphitic schist and fuchsite rock; the former has been driven on to the north for a considerable distance at these levels, but there is no record as to what values were obtained, though probably there was a certain amount of impregnation along this line from the cross veins.

The western shear zone has been driven on to the southern boundary at the 95ft. and 190ft. levels and for about 210 feet south at the 388ft. level. At the two former levels much work has been done on the cross quartz veins, as also at the 100ft. level from Tweedie's shaft near the north-east corner of the open-cut, chiefly on the eastern side of the western shear zone. Values are poor in the leaders in the immediate vicinity of the shear zone, which faults them to the north going west—the faulting is greatest, usually a few feet, along the hanging-wall plane of the shear zone, but the leaders are also faulted a few inches along the footwall and intermediate planes. In the sulphide zone the gold content of these veins is probably as high as in the oxidised zone, but owing to the greatly increased hardness of the country rock, and the fact that the veins are "frozen" thereto, mining is more difficult and the costs higher.

There is an old 30-head battery north of the main shaft; this is no longer in use. Mr. H. Raven, to whom the leases belonging to the Hannans Reward Co. have been sub-leased, treating the ore

Fig. 27.

G.M.L. 211E, "Charlotte" Open Cut from North.

Photo: F. R. Feldtmann. Neg. F192.

therefrom at his own plant on G.M.L. 796E. A winding engine is, however, in use at the main shaft.

Hannan's Hill G.M.L. 97E (*vide* Plate X.). This lease is situated to the south of G.M.L. 211E. Like the latter, it has been let to Mr. Raven, the southern portion of the lease being, at the time of my inspection, further sub-let to Messrs. Shepherd Bros., the holders of G.M.Ls. 415E, 1163E, and 14CE.

Fig. 28.

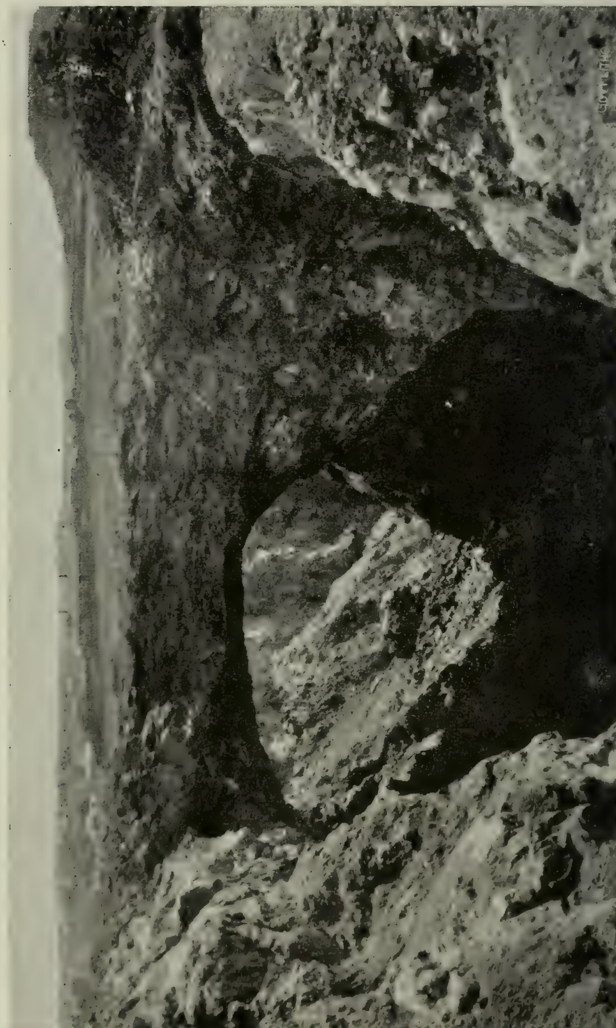


Photo: F. R. Feldtmann. Neg. F193.

G.M.Ls. 211E and 97E, looking N. from Northern Open Cut, on 97E, into "Charlotte" Open Cut.

As in the preceding leases, the extreme western portion of this lease is in quartz-dolerite amphibolite, the wide band of quartz-dolerite greenstone occupying the middle of the lease. A band of

amphibolite, entirely obscured, probably lies to the east of this, while still further to the east is the band of fuchsite-carbonate-quartz rock met in G.M.L. 211E, intersected by an albite-porphyrite dyke and several lenses of jasper, probably graphitic at depth. The latter can be seen outcropping in places, near the old water-shaft.

The shear zones running through the last-mentioned lease pass through this lease also, the "Charlotte" shear zone being cut in a crosscut west from Barnfield shaft, at the 80ft. level; this shaft is situated near the south-west corner of the "Charlotte" open-cut. This western shear zone has only been driven on for a few feet in this lease, but a good deal of driving has been done on the "Reward" shear zone. East of this shear zone, and joining it immediately south of the open-cut about two chains north-east of the main shaft is another shear zone, apparently of a similar character, but striking approximately N.W.-S.E.; this can be seen in places in the open-cuts near the southern boundary of the lease and in the workings from the Cassidy N. (G.M.L. 1163E) main shaft, while a parallel shear zone, roughly two chains south-west of the last, can be seen on the western side of the open-cut on the southern boundary of the lease. Whether these N.W.-S.E. striking formations are true lodes or belong to the latter series of barren shear zones, is difficult to determine, the writer having no opportunity of examining them at depth; their strike is in favour of the former, but their general characteristics and low value in the oxidised zone, together with the fact that they apparently do not exist to the west of the N.-S. shear zones, are decidedly in favour of the latter view. Numerous minor shear zones and fault planes occur on the mine.

As in the previous lease, the cross quartz veins are the main source of the gold in this lease, but here the flatter E.-W. series predominates. Examples of the steeper series occur, but are not so common as, and are steeper in dip than in G.M.L. 211E, being practically vertical at the southern end of the lease. In a specimen [**2772**] from a cross vein from the bottom level of the main shaft, splashes of telluride occur associated with free gold; this is the only occurrence of tellurides in these cross veins recorded.

The main or "Reward" shaft, which has a depth of 518 feet, is situated on the top of the hill from which the lease takes its name. The workings are very extensive, levels having been driven at depths of 80, 138, 197, 295, and 493 feet; only the first three were accessible at the time of this survey. North and south drives traverse the lease from end to end at the 80ft. level, from which much stoping has been done on the cross leaders, particularly in the southern portion of the lease, where the workings resemble a rabbit warren. The eastern workings at the 80ft. level are connected by winzes with a long drive north at the 80ft. level from

the Cassidy's North main shaft, the Cassidy's North 80ft. level corresponding to one of 114 feet as measured from the surface at the "Reward" shaft. A good deal of work has been done at the 197ft. level, where long drives have been put in to the north and south, the latter nearly to the boundary of the lease, following the shear zones, which were evidently regarded as true lodes.

There are numerous shallow shafts on the lease, either on the cross veins or connecting with the 80ft. level in the vicinity of cross veins. There are several large open-cuts on this lease—the northernmost connecting with that on G.M.L. 211E—in which both leaders and the intervening country have been worked on a large scale.

HANNAN'S REWARD G.M.L. 160E. This lease adjoins G.M.L. 97E, and is the southernmost belonging to the Hannan's Reward Co.; the boundary between the quartz-dolerite amphibolite and greenstone passes through the lease. There are three shafts on the lease, of which one—"Hannan's" shaft—on the northern boundary connects with the south drive at the 80ft. level from the "Reward" shaft. Opposite Hannan's shaft long crosscuts run east and west to the boundaries of the lease; the western one, which, unfortunately, was mullocked up, evidently cuts the Charlotte shear zone at about 280 feet west (along the crosscut) of the shaft.

Returns supplied by the Mines Department Statist for the leases held by the Hannan's Reward, Ltd., are as follows:—

Numbers of Leases.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
97E, 160E, 211E, 212E, 213E, 1653E	312,824·31	72,806·35*	0·23

* Includes 2·58ozs. specimens and dollied.

CASSIDY HILL G.M.L. 4E (Figs. 29 and 30). This lease lies to the south of and adjoining the previously described lease; its south-western boundary crosses the Boulder Railway line. Now owned by Mr. A. G. Hadden, it was formerly one of the Paringa Mines, Ltd., leases.

The eastern and greater portion of the lease is in quartz-dolerite greenstone, the western in the corresponding amphibolite, intermediate phases occurring between the two.

The Charlotte and Reward shear zones apparently pass into the lease, although the former had not been cut in any of the workings

accessible to the writer; the latter is seen as a thin shear zone in the crosscut at the 180ft. level connecting the main shaft with No. 2 shaft.

The workings have disclosed no lode formations on the mine. All the gold, as with the Hannan's Reward leases, being obtained

Fig. 29.

Photo: F. R. Feldtmann. Neg. F196.

From top of Mt. Gledden looking North, Cassidy Hill Main Shaft on top of first hill, Reward Shaft behind it, Cassidy N. Shaft and Plant on right, Mt. Charlotte in background.

from the cross quartz veins of both series. Numerous small fault planes are found to cut the cross veins, throwing them to the north,

going west, for distances varying from a few inches to about five feet (*vide* Plate VIII.), and the country in general is much jointed.

The main shaft, situated on the top of the hill, has a total depth of 180 feet from the surface, levels having been driven at depths of 63, 95, 118 and 180 feet.

Fig. 30.

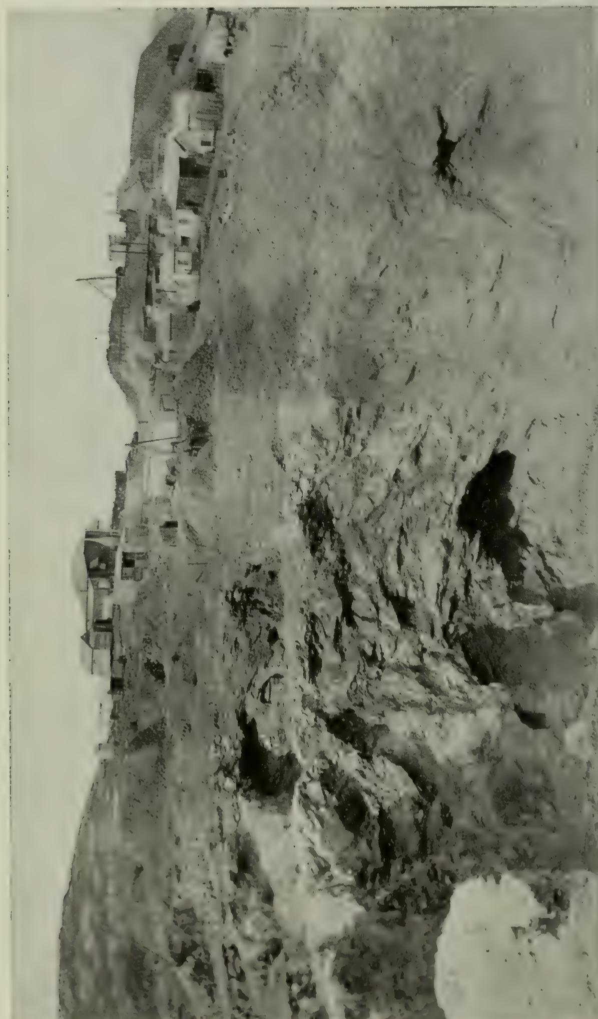


Photo: F. R. Feldtmann. Neg. F195.

Looking S., Southern Open Cut on G.M.L. 97E, Mt. Gledden in background, Cassidy Hill Main Shaft to right.

The steeper series of cross veins dips slightly to the south in this mine; a good deal of work has been done on these at the 63 and

118ft. levels. The flatter series have, however, been most persistently worked, particularly the No. 4 and No. 2 veins.

In one of the vertical veins close to the southern boundary in the 120ft. level from No. 1 shaft a small rich patch, showing much free gold, was associated with galena, hæmatite and a ferriferous carbonate. Some of the gold shown the writer from veins in the oxidised zone resembled that resulting from the decomposition of tellurides.

There is a small treatment plant on the mine.

Part of the returns for this lease are unfortunately combined with those from G.M.L. 392E outside this area, which was also one of the Paringa Mines, Ltd., leases.

The returns supplied are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4E, Cassidy Hill	2,313·50	6,758·64*	2·92
4E, 392E, Paringa Mines, Ltd. ..	64,853·72	29,379·50	0·45
	67,167·22	36,138·14	0·54

* Includes 1,788·09 fine ozs. from specimens and dollied ; 13·9ozs. of silver were also obtained.

CASSIDY'S NORTH G.M.L. 1163E. This lease, originally G.M.L. 3E, together with the adjoining G.M.Ls. 415E and 14CE, forms part of the Hannan's Consols leases, formerly the Hannan's Consols, Ltd. It adjoins the Hannan's Hill and Cassidy Hill leases.

The south-western half of the lease is in quartz-dolerite greenstone, the north-eastern half in the corresponding amphibolite. Much of the surface is hidden by a slimes dump. The southern portion of a small albite-porphyrite dyke runs through the northern corner; on the south-western side of this dyke is a small body of jasper. The northern portion of the albite-porphyrite dyke which runs to the south-west of Williamstown also runs through this lease, and can be seen at the 80ft. level from No. 3 shaft. There is another jasper formation about 14ft. wide on the south-western side of this dyke.

The two N.W.-S.E. striking shear zones which run into the Reward shear zone, run through this lease, the north drive at the 80ft. level from the main hauling shaft following the north-easterly one. The main shaft is situated 160 feet north of the south corner of the lease. North-west of the main shaft there are two large open cuts, with a third one crossing the boundary between this lease and

G.M.L. 97E. As usual, both cross veins and country from these cuts have been milled. Numerous shafts have been put down on the lease, on cross veins. No. 3 shaft has a depth of 290 feet, and at this depth a long crosscut connects with the Lady Elizabeth No. 1 shaft.

There is a small treatment plant on this lease.

Returns for this lease and G.M.Ls. 415E and 14CE are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
14CE, 415E, 1163E, Hannan's Consols Leases	52,012·67	10,228·06*	0·20

* Includes 2·84ozs. alluvial and 276·35 fine ozs. dollied and specimens.

LADY ELIZABETH G.M.L. 415E. This lease adjoins the last on the north-east. Roughly the western third of the lease is in quartz-dolerite amphibolite, the eastern two-thirds in dolerite-greenstone. The southern portion of a prominent jasper formation, best developed on a small hill to the north, runs into the lease and has been cut in the workings from the main shaft at depths of 96 and 296 feet. The main shaft is 306 feet deep. Some specimens of talc-chlorite-carbonate rock, probably occurring near the jasper, were found on the dump. The south-western end of another prominent jasper striking N.E.-S.W. crosses the north-eastern boundary. The previously mentioned albite-porphyrite dyke running south-west of Williamstown crosses through the southernmost portion of the lease.

Nothing of value appears to have been found on this lease, which has not been well prospected.

CALEDONIAN G.M.L. 14CE. This lease lies to the south of and adjoining G.M.Ls. 415E and 1163E. The south-western two-thirds are in quartz-dolerite greenstone, the remaining third in quartz-dolerite amphibolite, somewhat gabbroid in places, judging from Mr. Campbell's description. This portion of the lease is, however, hidden by the slimes dump. The westernmost of the two jaspers found in G.M.L. 1163E runs close to the north-eastern boundary of this lease.

There are several shallow shafts put down on cross veins in the greenstone in the southern portion of the lease.

MARITANA G.M.L. 279E. This lease adjoins the south-eastern boundary of G.M.L. 4E, and together with G.M.L. 2E (and formerly 3770E, now voided) forms one of the Maritana group of leases.

It is entirely in quartz-dolerite greenstone, but most of the surface is obscured by superficial deposits in which much dry-blowing has been done. The northern portion of the Maritana lode runs into this lease.

Several shallow shafts have been put down on cross veins in the lease, and a water shaft was put down to a depth of 258ft. on the road to Williamstown, near the south-western boundary of the lease; this shaft has been filled in.

Returns for the Maritana leases are given below:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
2E, 279E, Maritana G.M. Co., N.L.	11,373·50	4,660·82*	0·41
2E, 279E, 3770E, Maritana Leases	20,347·63	8,623·74*	0·42
3770E, Eaglehawk United ..	4,161·56	4,118·30*	0·99
Totals	**35,882·69**	**17,402·86***	**0·48**

* Includes alluvial, dollied, and specimens.

Maritana G.M.L. 2E (Fig. 31). This adjoins the south-eastern boundary of G.M.L. 279E, and covers practically the whole of Mt. Gledden. It is entirely in quartz-dolerite greenstone. A lode formation striking N.W.-S.E. runs through the north-western portion of the lease; its south-eastern extension has not been followed. A fair amount of work has been done on the northern portion of this lode from the surface down to the 75ft. level from the main shaft, which is situated on the north-west slope of the hill, close to the corresponding boundary of the lease. Apparently this lode has not been cut in the lower levels of the mine, which are not sufficiently far to the west. A N.-S. shear zone, which was apparently taken for the lode, was cut in the west cross-cut at the 140ft. level (Fig. 32). This shear zone has faulted a cross quartz vein, and has also acted as a channel for vadose waters, the country on the western side at the 140ft. level being oxidised, that on the eastern unoxidised (Fig. 33).

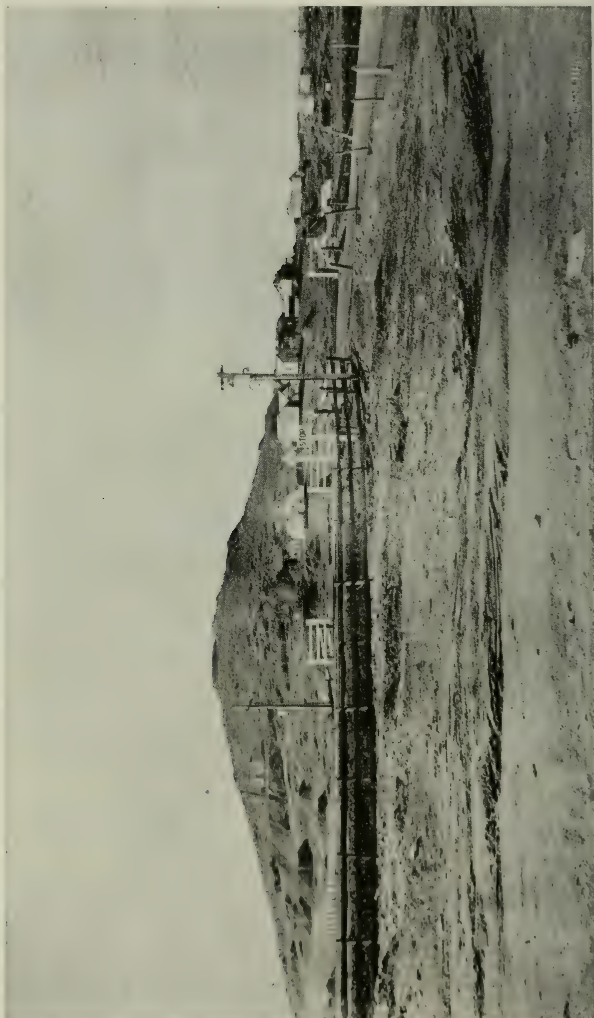
A description has already been given of the lode formation, which has also been cut in an adit level in the south-western side of the hill.

There are numerous cross veins belonging to both series in the lease, and a good deal of work has been done on these from time to time.

Eaglehawk United G.M.L. 3770E (voided). This lease adjoins the south-western boundary of the preceding lease and crosses the Brown Hill Railway line. The south-western

two-thirds are in quartz-dolerite amphibolite, the north-eastern third in quartz-dolerite greenstone. The northerly extension of the barren lode from the former Hannan's Find, G.M.L. 4470E, runs into this lease at its southern end. Three shallow shafts have been sunk on

Fig. 31.



Neg. F197.

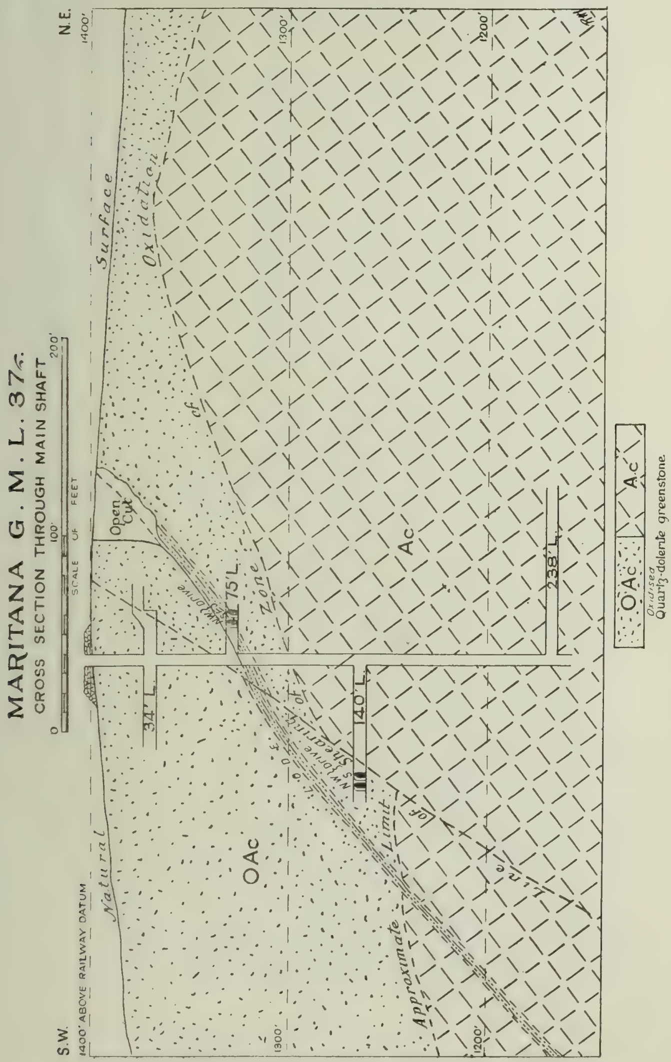
Mt. Gledden and Maritana Main Shaft (on left) from the West.

Photo: F. R. Feldtmann.

this, apparently without finding payable values. The gold from this lease has evidently been largely obtained from cross quartz veins, or from superficial deposits.

The lease has been fairly well prospected, particularly at the 73ft. level, connecting three shafts near the middle of the lease. From the dump of the central one of these, specimens evidently from a lower level, now inaccessible, were obtained of a very coarse

Fig. 32.



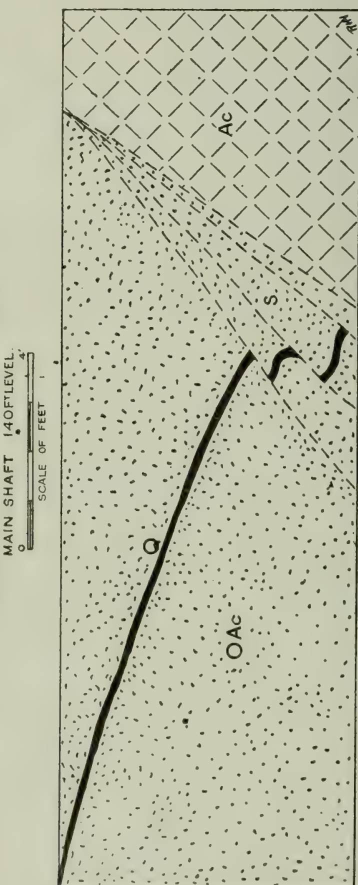
pegmatitic variety of the quartz-dolerite amphibolites mentioned when dealing with those rocks. A cross vein, up to 14 inches in

thickness, dipping south at a steep angle, had been followed near the northernmost of the three shafts; it appeared to contain a good deal of manganese oxide.

Lord Nelson G.M.L. 4477E (Figs. 34 and 35). This lease adjoins the south-eastern boundary of G.M.L. 2E; the ground was formerly part of G.M.L. 4303E, Sir John Forrest—the latter being

Fig. 33.

MARITANA G.M.L. 37e



Cross section showing irregularity of zone of oxidation along a shear zone – S the latter faulting a cross quartz vein Q in quartz-dolerite greenstone Ac (oxidised · OAc).

previously held as G.M.L. 501E of the same name—G.M.L. 1591E, Sir John Forrest Extended, and G.M.L. 2988E, Little Duke, belonging to the Paringa Mines, Ltd.

The main belt of quartz-dolerite greenstone ends in this lease, the greater portion of which is in amphibolite. A N.-S. shear zone

runs through the middle of the lease. There are numerous cross quartz veins of both series, on which a good deal of work has been done, particularly at the northern end of the ground.

Fig. 34.

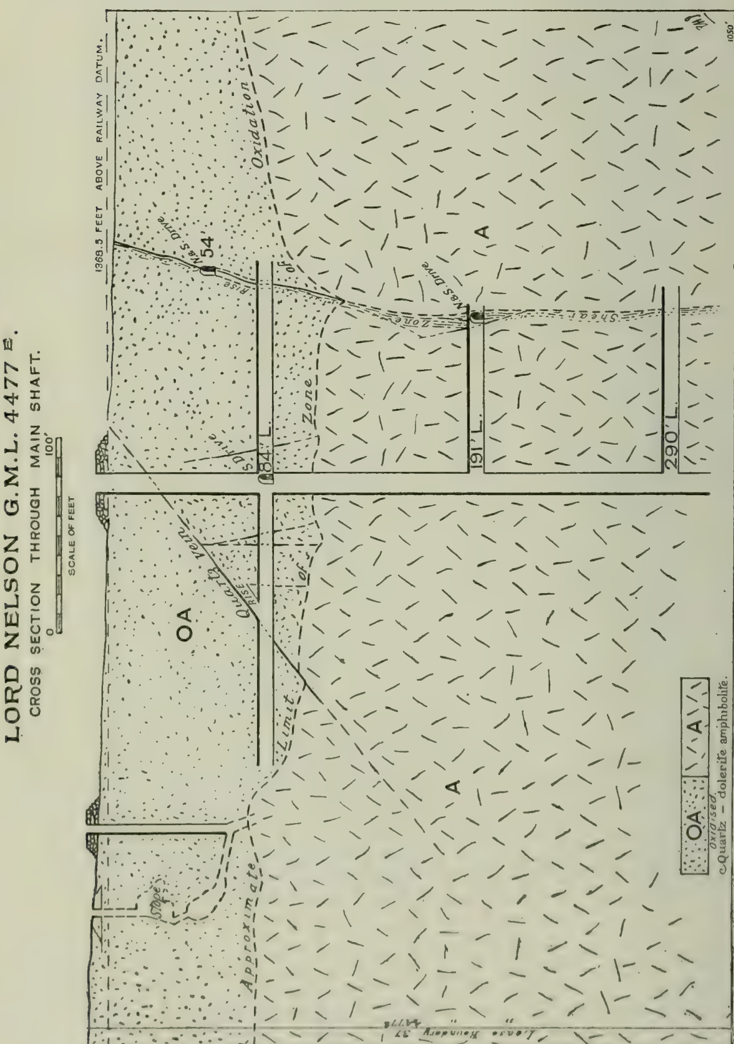
Photo: F. R. Feldtmann. Neg. F198.

Mt. Gledden from the South, Lord Nelson Main Shaft at foot of slope on left.

The old main shaft is situated slightly west of the centre of the lease and has a total depth of 310 feet; levels have been driven at depths of 84, 191, and 290 feet; the shear zone has been driven on at each of these levels; the 84ft. level is connected by a rise with the

54ft. level from the No. 2 shaft, which is about 150 feet north-east of the main shaft. A little work has been done on cross veins at this level, and also at the 80ft. level. There are a number of other comparatively shallow shafts on the lease, and a good deal of dry-blowing has been done on the western half.

Fig. 35.



The only returns are for this lease and G.M.L. 4303E.

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4477E, Lord Nelson	2,024·38	755·36*	0·37
4303E, Sir John Forrest	132·52	104·42*	0·79
Total	**2,156·90**	**859·78***	**0·40**

* Includes dollied and specimens.

HANNAN'S FIND G.M.L. 4470E (voided) and HANNAN'S FIND EX. G.M.L. 4471E (voided). These leases, which were held as the Hannan's Find leases, were situated between the Boulder and Brown Hill Railway lines, to the south-west of G.M.L. 4477E, which G.M.L. 4471E adjoined. The ground covered by G.M.L. 4470E was formerly part of G.M.L. 4056E of the same name, and, prior to that, part of the ground was held as G.M.L. 9E, Bohemian Girl, while the ground covered by G.M.L. 4471E was formerly part of G.M.L. 1511E, Lady Forrest.

The area occupied by these leases is entirely in quartz-dolerite amphibolite. A fairly long line of lode, splitting to the north, runs through G.M.L. 4470E and through former G.M.L. 42E (154) into the old Eaglehawk United. An unusual feature of this lode is the marked dip to the north-east. Although fairly well defined, this lode is practically barren, as might be expected from the nature of the country rock. A little work was done on it from the Lady Forrest and Bohemian Girl main shafts; the latter is situated on the top of a small laterite hill, under which a great deal of work has been done, the infralaterite being impregnated, in the usual fashion, with gold from cross quartz veins, of which there are a number on the ground, though perhaps not to the same extent as in the greenstone country. Most of the ground has been dry-blown.

Returns for these and former leases are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4470E, Hannan's Find	140·00	27·38	0·19
4470E and 4471E, Hannan's Find Leases	1,132·00	196·45	0·17
4056E, Hannan's Find	1,506·00	291·74*	0·19
9E, 37E, 42E, Hannan's Find Gold Reefs, Ltd.	83·50	28·79	0·34
Totals	**2,861·50**	**544·36**	**0·19**

* Includes 6·06 fine ozs. alluvial.

CONUNDRUM G.M.L. 4401E (voided). This lease was situated on the north-east side of the Brown Hill Railway line, and south-east of the Lord Nelson. It was formerly G.M.L. 4295E, Lady Wallace, and prior to that the northern part of the ground was held as G.M.L. 4150E, Found at Last, and the southern part as G.M.L. 4126E, Cardigan. At an earlier date the ground was covered by G.M.L. 1028E, Golden Point, held by the Hannan's Proprietary Development Co., Ltd.

The north-western half of the lease is in quartz-dolerite amphibolite, the south-eastern in fine-gained greenstone. A N.-S. shear zone, dipping to the west at about 55°, occupies the junction of the two rocks; near its northern end this joins a N.W.-S.E. striking formation, which occurs in the fine-grained greenstone. It is uncertain whether this latter formation belongs to the lode formations, or is merely another shear zone; in any case it does not appear to carry payable values.

There are several comparatively shallow shafts on the ground, some on cross quartz veins in the amphibolite. The veins in this lease are mostly small, and the unoxidised rock not being far from the surface in the southern portion of the amphibolite area, they are not always payable. From a shaft put down by the Hannan's Proprietary Co. in the southern portion of the lease, long crosscuts were put in to the north-east and south-west at the 75ft. level, the latter crosscut cutting the N.-S. shear zone, on which a little driving was done without payable results.

With the exception of a few cross quartz veins no payable formation is likely to be found on this lease.

Returns are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4295E, Lady Wallace	114·00	6·41	0·06
4150E, Found at last	..	9·51*	..
4126E, Cardigan	47·00	9·67	0·21
Totals	**161·00**	**25·59**	**0·16**

* Dollied and specimens.

DEVON CONSOLS G.M.L. 4532E (voided) (Fig. 36). The ground covered by this lease was previously G.M.L. 3880E, and, prior to that, G.M.L. 3811E of the same name; it was first held as G.M.L. 1731E, Mt. Charlotte East. It lies to the south of the Union Club G.M.L. 4289E. The Transcontinental Railway line now runs through the ground, which is almost entirely in dolerite greenstone; the

long line of jasper mentioned in the description of those rocks runs right through the lease, and on the east side of this, in that portion of the ground south of the Transcontinental Railway, is the north-

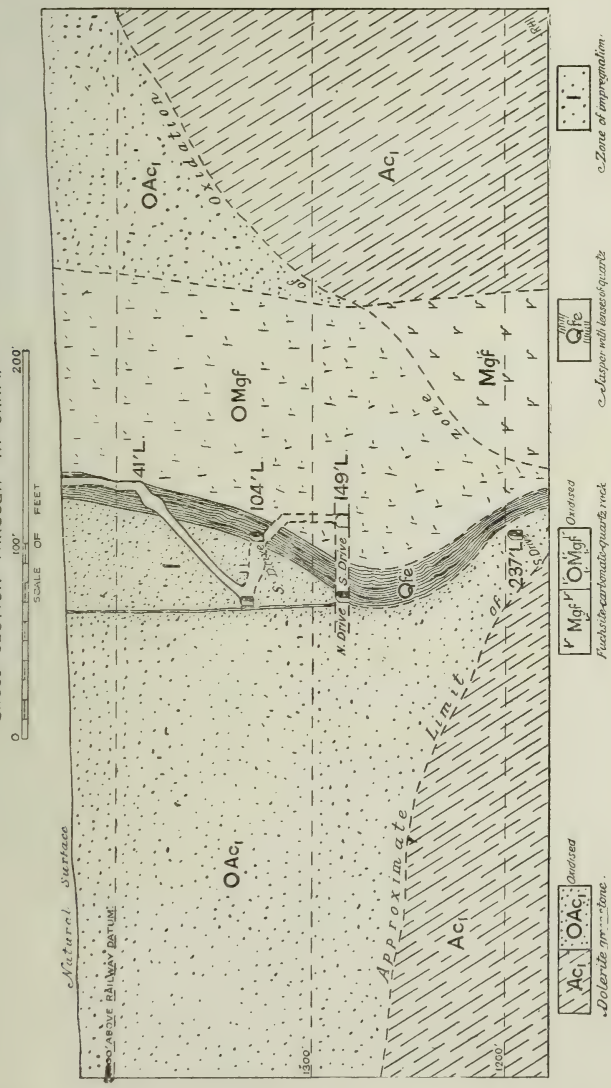


Fig. 36.

DEVON CONSOLS G.M.L. 1731E

CROSS SECTION THROUGH 41FT SHAFT.

erly extension of the long line of fuchsite-carbonate-quartz rock which starts south of the Hidden Secret. In the Devon Consols

this belt of fuchsite rock is ill-defined. A laterite-capped hill occupies the south-eastern corner of the lease.

There appears to be no defined lode formation on this lease, but the workings disclose a number of cross quartz veins, which cut into the jasper for a few feet. Some veins are very flat, and are bunchy and irregular near the jasper. There is said to have been a good deal of coarse gold at their junction with the latter, and they are probably responsible for the gold obtained from the oxidised country in its vicinity.

The main shaft is situated about 400 feet south-east of the north-west corner. I was unable to ascertain its total depth. The hanging wall of the jasper has been driven on for over 1,100 feet at the 149ft. level, and over 800 feet at the 237ft. level. A fair amount of work has also been done in the southern portion of the lease at the 100ft. level, which is connected by an incline rise with a shaft 41 feet in vertical depth, and rather more than 400 feet north of the south-west corner. At the 149ft. level the jasper is mainly composed of a varying width of pale yellowish-grey slaty laminæ, on the eastern side of which are a number of large irregular brown flinty quartz lenses. Near the southern end of the 237ft. drive the sulphide zone is met with and the jasper is replaced by graphitic schist.

The following are returns as supplied by the Mines Department Statist:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
3880E, 4146E, Devon Consols Leases	26,777·00	11,686·92*	0·44

* Includes 36·73 fine ozs. dollied and specimens.

Sons of Gwalia G.M.L. 3771E (voided). The ground covered by this lease adjoins the southern boundary of the Devon Consols. At one period it, together with G.M.Ls. 796E and 1228E, was held as one of the Bonnie Lass leases. At an earlier date it was taken up as G.M.L. 1623E, Reefer's Trident.

The western portion of the ground is in dolerite greenstone, the eastern in talc-chlorite-carbonate rock, while the middle is occupied by the southerly continuation of the Devon Consols line of jasper, with fuchsite-carbonate-quartz rock to the east of the latter.

There are a number of shafts on the ground, but only one—120 feet north from the middle of the southern boundary and about 20 feet west of the jasper—was accessible at the time of my visit;

this shaft has a total depth of 99 feet from the surface, and there were levels at depths of 28, 73, and 99 feet; in the north drive at the latter level was a winze in sheared oxidised rock to the west of the jasper; this winze reached a depth of 127 feet from the surface; from the bottom of this winze a small drive and crosscut led to the west wall of the jasper, on which was another winze, to a depth of 171 feet from the surface. The jasper was cut in the east crosscut at the 99ft. level, and was 33 feet wide here, the western 20 feet consisting of finely laminated grey slaty bands of cryptocrystalline quartz highly contorted in places (*vide* Fig. 7), the eastern 13 feet of coarse lenses of dark grey flinty quartz separated by bands of ferruginous crumbly and highly laminated matter. There are a number of steep northerly-dipping cross quartz veins on both sides of the jasper, usually pinching before actually reaching it. At the 73ft. level a crosscut connects with a shaft 170 feet west of the last, and continues for a further distance of 155 feet; an ill-defined formation striking about N.W.-S.E. and dipping S.W. at about 54 degrees was cut in this latter portion of the crosscut; it contains a few thin lenses of flinty quartz, but does not appear to have carried values.

A good deal of dryblowing has been done near the eastern corner of the lease.

Returns for this lease are given later with those of the other Bonnie Lass leases.

Red White and Blue G.M.L. 1228E (Fig. 37). This lease lies to the south of the previously described lease, and east of G.M.L. 213E.

With the exception of a band of albite-porphyrite, running diagonally through the lease—the south-eastern branch from the main dyke of that rock—the whole of the lease appears to be in dolerite greenstone; the country rock is, however, obscured by superficial deposits, and none of the workings appear to have got below the limits of the oxidised zone.

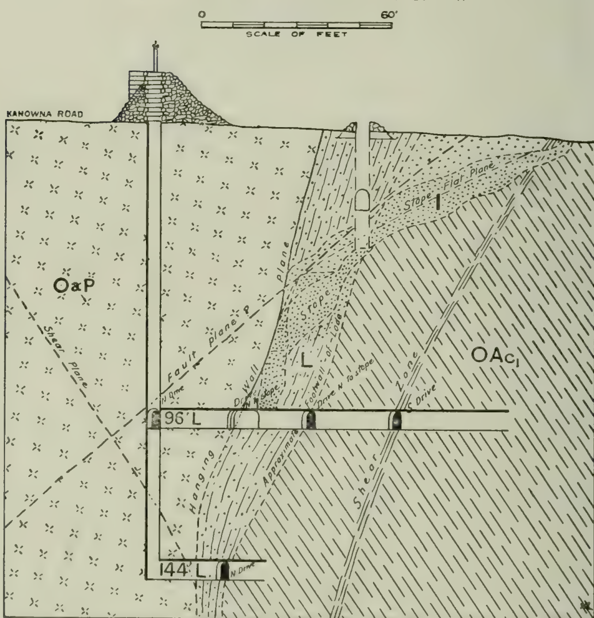
A lode formation occurs on the eastern wall of the albite-porphyrite, apparently the southerly continuation of the Mystery line of lode. The hanging wall of this lode is fairly well defined and, so far as can be judged in the oxidised zone, is on the junction of the two rocks. Another shear zone, striking more north-westerly and cut in the east crosscut at the 96ft. level, runs to join the lode on the eastern side of the latter, and may have had some influence on the distribution of values, as a small but very rich shoot of ore was found near the junction of the two. In the stope near the surface (*vide* Fig. 37) is a thin flat vein of ironstone, evidently marking another line of shearing; this also runs into the hanging-wall

plane, and the country in its vicinity has been impregnated to some extent. The rich shoot carried some beautiful specimens of sponge gold, and I was informed by Mr. C. de J. Grut, attorney for the Hannan's Reward, Ltd., that the oxidised ore, which he had personally tested, showed a strong reaction for tellurium. This is in favour of the permanency of the formation, and further prospecting will in all probability reveal other shoots of ore.

Fig. 37

G.M.L. 1228 E

CROSS SECTION THROUGH MAIN SHAFT.



Showing lode formation-L at junction of albite-porphyrite OaP *(oxidised)* and dolerite-greenstone OAc1 *(oxidised)*. Ore shoot I.

The main shaft from which the ore-body is worked is situated on the eastern side of the Kanowna Road, and is 144 feet in depth. A good deal of work has been done at the 96ft. level, and there is a short crosscut and a north drive on the lode at the 144ft. level. There are numerous other shafts on the lease, but none were accessible at the time of my visit.

A number of cross quartz veins west of the main jasper have been worked near the eastern boundary of the lease. Most of the surface has been dryblown.

Bonnie Lass G.M.L. 796e.

This lease lies to the southwest of and adjoining G.M.L. 1228e, and also adjoins the eastern boundaries of G.M.Ls. 4529e and 211e.

In the northern portion of the lease, none of the workings appear to have gone below the limit of oxidation and the exact nature of the country rock is doubtful, but it is most probably quartz-dolerite greenstone. A band of talc-mesitite rock occupies part of the south-western portion, being exposed on the dump of an inaccessible shaft 280 feet north-east of the south corner of the lease and said to be 249 feet in depth. To the south-west of the talc-mesitite rock is the continuation of the band of fuchsite-carbonate-quartz rock met with in the eastern workings from the "Charlotte" main shaft. In this fuchsite rock is a dyke of albite-porphyrite and a wide band of graphitic schist; these are exposed in the workings from a shaft near the western boundary and 170 feet north of the south corner. The prominent laterite-capped hill mentioned in the description of G.M.L. 4529e extends across the northern end of this lease. Four shafts have been sunk through it, one, now inaccessible, to a depth of 162 feet, another, which I was able to examine, to a depth of 107 feet. From the last-mentioned shaft levels have been driven at depths of 28, 48, 69 and 107 feet; a great number of cross quartz veins usually dipping steeply to the north, and only a few feet apart, have been worked from these levels (*vide* Fig. 18). In many instances they seemed to be vein systems rather than simple veins. On the walls of some of these veins was a little green, probably chromiferous puggy material, and a thin fuchsitic seam was observed at the southern end of the south drive at the 69ft. level. At the 107ft. level, a long croscut east connects with the west crosscut from a shaft 112 feet deep just inside G.M.L. 1228e. At the junction of the two crosscuts is a winze to a depth of 184 feet from the surface. About 40 feet from the shaft on G.M.L. 1228e the country changes and becomes paler and numerous "soapy heads" are present. Owing to the decomposed state of this rock it is impossible to determine its origin. It may have been either highly sheared and altered greenstone, or albite-porphyrite.

From the previously mentioned shaft on the jasper near the south corner of the lease, levels have been put in at depths of 35 and 203 feet. The east crosscut at the former level cuts the albite-porphyrite dyke; towards the eastern end of the crosscut this dyke is more sheared and contains numerous greenish inclusions. The jasper is best seen at the 203ft. level, where it consists mainly of grey slaty laminæ, but ferruginous in places; it appears to be more graphitic near the western wall. A winze from this level reaches a total depth of 263 feet from the surface—this was inaccessible.

There is a 10-head battery and a cyanide plant on this lease.

Returns for the Bonnie Lass leases are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
796E, 1228E, Bonnie Lass Leases	6,011·00	6,105·91*	1·01
796E, 1228E, 3771E, Bonnie Lass Leases	11,307·65	6,461·52	0·57
796E, 1228E, Hannan's Reward N. G.M. Co., N.L.	334·00	264·21*	0·79
1228E, Red White and Blue ..	130·00	25·56	0·20
3771E, Sons of Gwalia	1,428·00	844·54	0·59
Totals	**19,210·65**	**13,701·74***	**0·71**

* Includes Dollied and specimens.

Hannan's Reward North G.M.L. 4528E.

This lease adjoins the southern boundary of G.M.L. 1228E and the eastern boundary of G.M.L. 796E, and like them, is held by Mr. Raven. The ground was formerly part of G.M.Ls. 4440E Battler, and 4057E Criterion; G.M.L. 4440E was formerly held as G.M.L. 4115E Sarnian, and prior to that formed part of G.M.L. 3964E Belgravia, and at an earlier date G.M.L. 2688E Hannan's Hill Extended. G.M.L. 4528E also includes a small portion of former G.M.L. 4438E Battler East, formerly G.M.Ls. 4385E A.I., 4113E Hidden Fortune, and 4043E Orkedon.

The continuation of the albite-porphyrite branch which runs through the Red White and Blue appears to run through this lease, the rest of which is in dolerite-greenstone. Crossing the southern boundary is the northerly extension of the prominent jasper body which runs through the Lady Elizabeth.

There were only three shafts on the ground at the time of my visit, all being inaccessible. On the dump of one near the eastern boundary, graphitic schist was much in evidence; the workings from this shaft—said to be 150ft. deep—were inaccessible, but a crosscut is said to have been put in to the north-west, in which values were obtained. As the Red White and Blue albite-porphyrite dyke apparently runs through this lease, it is probable that the lode on the eastern side of the dyke also runs into this ground, and the values from the above-mentioned crosscut may be from the vicinity of this lode which should be worth prospecting. A crosscut west from this shaft would probably cut the lode at roughly 140 feet west of the shaft.

There are no returns for this ground, but those for former leases covering the voided area to the south-east are given below:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4438E, Battler East	44·00	3·70	0·09
4113E, Hidden Fortune	10·00	3·80	0·38
Totals	**54·00**	**7·50**	**0·14**

HIDDEN SECRET NORTH G.M.L. 4035E.

This is the northernmost of the Hidden Secret leases; it lies to the south of the former Battler East, and to the east of the Lady Elizabeth, but is separated from the latter by a narrow strip of vacant ground. The ground was formerly the southern portion of G.M.L. 254E Holdings' lease.

The western portion of the lease is in dolerite-greenstone, the eastern in actinolite-zoisite amphibolite, but in places in the area occupied by the former, intermediate stages between the two rocks are found; for instance, on the dump of a shaft half way along the south-western boundary. A number of thick N.E.-S.W. striking jasper lenses are a prominent feature in the north-western portion of the lease.

Besides the shaft on the south-western boundary, there are three other shafts on the ground; the northern two are connected by a long crosscut at the 75ft. level (in oxidised rock) the greater portion of this crosscut runs through the above-mentioned jasper, which is somewhat contorted and shows numerous small fault and joint planes; south-east of the jasper the country is jointed, and shows bleaching in places. From the northernmost shaft, which is 140 feet deep, drives run north and south at the 75ft. level on a somewhat ill-defined formation with some lenses of flinty quartz; this formation is apparently on much the same line as the main Hidden Secret lode, but it is evidently unpayable.

Much of the surface has been dryblown.

HIDDEN SECRET G.M.L. 4001E (Fig. 38). This lease adjoins the south-eastern boundary of the Hidden Secret North, and was formerly part of G.M.L. 1034E, Hidden Treasure South, of the Hannan's Proprietary Development Co., Ltd.

The western and larger part of the lease is in dolerite greenstone, the eastern in talc-chlorite-carbonate rock. A band of fuchsite-carbonite-quartz rock, with a westerly dip of about 59 degrees,

runs through the eastern portion of the lease at the surface; at the 198ft. level, where it has been driven on for some distance, it is about in the middle of the lease, and it cuts across the main shaft at a depth of 360 feet from the surface to join the main lode, which dips more steeply, just about the 404ft. level (*vide* Fig. 15).

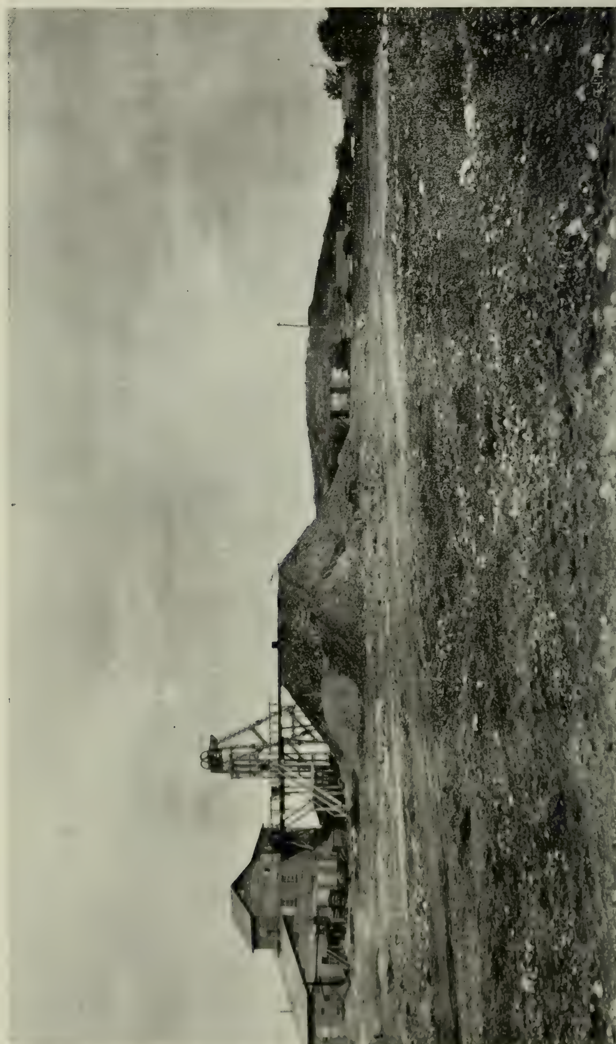


Fig. 38.

Neg. F199.

Hidden Secret Main Shaft from North.

Photo: F. R. Feldtmann.

The main shaft is situated about 290 feet north of the southern corner of the lease; it is 430 feet in depth, and levels have been put

in at depths of 89, 198, 304, and 404 feet, while there are several intermediate levels on the lode in different parts of the mine, connected by winzes or rises with the main levels.

The main lode runs through the middle of the lease at the surface; north of the main shaft it splits into two branches which diverge at an angle of, roughly, 16 degrees; the junction between them appears to be nearly vertical, but pitches to the south between the surface and the 89ft. level. The rich shoot or "pipe" of telluride ore appears to have been closely connected with the junction of the two branches. This shoot has now been stoped out, and it is almost impossible to form any idea as to the shear lines which controlled the ore deposition, but it certainly occurred very close to, if not actually at, the junction of these branches. Its approximate position is shown on the longitudinal section (Plate VII.). The shoot was said to start at about 35 feet from the surface, lengthening out suddenly above the 89ft. level to about 15 feet between the 89ft. and 198ft. levels, the pitch was nearly vertical, and the length apparently fairly constant; at between 30 and 40 feet below that level it lengthened to between 30 and 40 feet, according to Mr. Gianini, shortening again suddenly and apparently pinching just above the 304ft. level; good values were obtained at that level below the shoot and in the winze between the 304ft. and 404ft. levels, and in the winze to 436 feet, near the southern end of the drive at 404 feet, good values were also obtained. At the time of my visit work was being carried on at the southern end of the drive at 404 feet.

The general structure and mineral composition of the lode were described in that portion of the report dealing with the ore deposits, and nothing further need be said here.

Other fairly rich shoots of ore have been worked in the upper levels, principally above the 89ft. level and on the eastern branch of the lode north of the main shaft, as may be seen on the longitudinal section; these appear to be of the usual roughly lenticular shape characteristic of the Kalgoorlie lodes.

Although rich shoots of telluride ore such as that of this mine occur under special conditions—depending largely upon the junction of two or more shear planes—and it cannot be expected that others equally rich will be found except under similar conditions, there seems to be no reason why other shoots of payable ore should not be found on this mine by further prospecting; in the search for these, the shear planes that have acted as "indicators" for the previously worked shoot should be carefully watched.

The plant consists of a 5-head stamp battery and one No. 4 Krupp ball mill, together with one Wilfley table and four cyaniding vats.

Hidden Secret South G.M.L. 4036e. This lease adjoins the south-eastern boundary of G.M.L. 4001e, and, like it, was formerly held as part of the Hidden Treasure South G.M.L. 1034e. As with the preceding lease, the western half of the ground is in dolerite greenstone, the eastern half in talc-chlorite-carbonate rock. The band of fuchsite rock appears to run through the middle of the lease, but is nowhere exposed, and its exact position is uncertain.

The main line of lode worked on this lease appears to run, roughly, from 40 to 70 feet to the west of that of the previously described lease, unless it should prove to be the same lode faulted to the west going south; the two, however, probably represent two distinct lines of shearing along a main zone. The main line of this lease is also found to split, in this case at its southern end.

The main shaft on this lease (B shaft) is situated about 240 feet west of north from the southern corner, and is 153 feet in depth, levels being driven at depths of 53, 99, and 153 feet, all in oxidised rock, with the exception of the extreme north end of the drive at the last level; sulphides were met in two winzes below this level. The general shape of the ore-shoot may be gathered from the longitudinal section (Plate VII.). The workings being practically all in oxidised rock, no description of the lode below the limit of oxidation can be given, but it probably closely resembles that of G.M.L. 4001e.

A good deal of work was done by the owners of the Hidden Secret leases further south on the same line of lode, from the "Federal" shaft now within G.M.L. 4501e, Secret Extended, and prior to that G.M.L. 4107e, Hidden Secret West, and G.M.L. 1099e, Central; Thornett Bros. also worked a shoot on this lode to the north of the Federal shaft, from a shaft near the western corner of G.M.L. 4051e, A.W.A. United. All these workings are shown on the longitudinal section. At the 155ft. level from the Federal shaft the unoxidised rock has been penetrated, the country in the vicinity of the lode is highly sheared and carbonated, and there are some large irregular lenses of quartz in the lode.

As no other work has been done on G.M.L. 4501e other than that from the Federal shaft, no special description of it need be given—it is entirely in dolerite greenstone and covers a large portion of the townsite of Williamstown on which practically no prospecting has been done, and within which it is by no means improbable that payable lodes may yet be found.

Returns for the Hidden Secret leases are given below, also those for the Hidden Secret West.

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4035E, 4001E, 4036E, Hidden Secret Leases	10,643·95	15,384·83*	1·45
4107E, Hidden Secret West ..	561·00	68·04	·12
Totals	**11,204·95**	**15,452·87**	**1·38**

* Includes 105·65 fine ozs. dollied and specimens, and in addition 43,383·29 fine ozs. of silver were extracted.

Great Secret G.M.L. 4450E (voided). This lease was situated to the south-east of and adjoining the Secret Extended. The ground was previously held as two leases, the northern being G.M.L. 4124E, Great Secret, and the southern G.M.L. 4281E, Mt. Ferrum West—the latter being included in the A.W.A. United leases. Prior to that the southern portion was G.M.L. 1111E, Phœnix, which, together with G.M.L. 1101E, was held by the Brown Hill Junction G.M. Co., N.L. The northern portion of the ground is in quartz-dolerite greenstone, the southern in fine-grained greenstone.

The southern end of the long line of formation which follows the junction of the Older and Younger Greenstones so closely runs through this ground; it has been cut in a small shaft 56 feet in depth and about 360 feet west of the east corner. In this shaft this formation in places presents the appearance of a spotted tourmaline-quartz-breccia mentioned in the description of the formation in that part of the report dealing with the Ore-deposits. Near the eastern corner of the lease is another line of formation, striking N.W.-S.E. and running towards the first-mentioned formation, which it should meet at approximately 210 feet N.N.W. of the south corner of the former A.W.A. lease; as fair patches have been obtained from similar junctions along the thin contact formation, this point is worth prospecting. Some work was being done by Messrs. Barrass and Hamilton on the N.W.-S.E.-striking lode from a 40ft. shaft about 110 feet east of the east corner of the ground, but values were said to be generally poor. 200 feet west of the same corner a shaft 103 feet in depth cut an E.-W.-striking formation dipping to the north at varying angles, but usually fairly shallow; this may be a fault line or a cross formation joining the two lode formations; it does not appear to fault the N.W.-S.E. lode so far as could be seen.

Returns for G.M.Ls. 4281E and 1111E are included in those for the A.W.A. United and Brown Hill Junction leases; those for G.M.L. 4124E are given below:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4124E, Great Secret	291·00	281·19*	0·97

* Includes 201·53 fine ozs. dollied and specimens.

Mt. Ferrum West Extended G.M.L. 4371E (voided).

This lease adjoined the south-western boundary of the preceding lease. It was formerly G.M.L. 4114E, Secret South, and prior to that portion of G.M.L. 1026E, Kalgurli, of the Hannans Proprietary Co.

With the exception of the westernmost portion, in quartz-dolerite amphibolite, the whole of the ground is fine-grained greenstone. The southern end of the Williamstown albite-porphyrite dyke crosses the north-west boundary of the lease with a jasperoid formation on its eastern wall.

There were only four shafts on the ground, all inaccessible; on the dump of the northernmost was a fairly coarse-grained highly-sheared rock, now a chloritic schist, with paler spots, now made up of an obscure mosaic; the rock is probably an exceptionally coarse variety of the fine-grained greenstones.

On the dump of the easternmost shaft were fragments of a white cellular rock showing a number of fine, black tourmaline needles; a little sericite was also present. This may represent a formation similar to the N.-S. line on G.M.L. 4450E.

There are no returns for this ground.

Brownhill Consols No. 2 G.M.L. 4356E (voided).

The ground covered by this lease adjoins the south-eastern boundary of the preceding lease. It was formerly held as G.M.L. 4119E, Montezuma, and prior to that was also part of G.M.L. 1026E.

It is entirely in fine-grained greenstone, but Mr. Campbell's map shows a narrow dyke of "felsite"—probably albite-porphyrite—as occurring in the east cross-cut from a shaft (No. 1), 350 feet south of the north corner. Cross-cuts have also been put in from the No. 2 shaft near the south-west boundary. None of these workings were accessible.

Apparently no values were obtained in the crosscuts, and there are no returns for the ground.

WILLIAMSTOWN G.M.L. 4499E (Fig. 39).

This lease lies to the south-east of former G.M.L. 4450E, and to the north-east of the previously described lease, and, like it, is

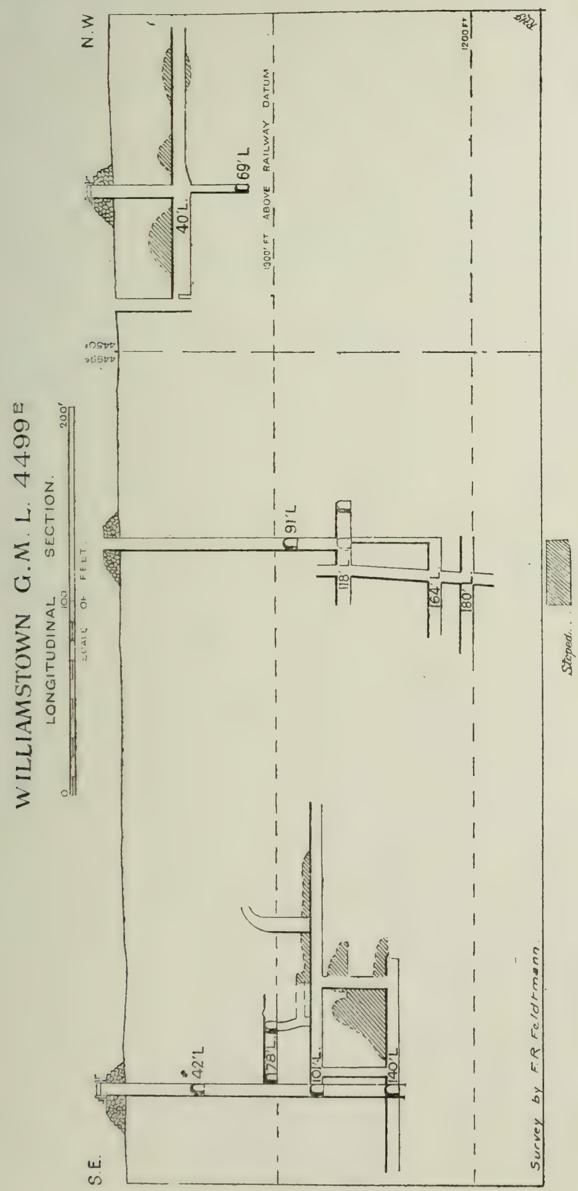


Fig. 39.

entirely in fine-grained greenstones. The ground was formerly held as G.M.L. 4302E, Mannajone, and at an earlier date as G.M.L. 860E, Brown Hill Consols North.

At the time of my visit the holders, Messrs. Sassella Bros., were working the same line of lode as Messrs. Barrass and Hamilton further to the north from a shaft about 415 feet south of the north corner of the lease, with a vertical depth of 145 feet; levels had been driven at depths of 42, 78, 101, and 140 feet, all in oxidised rock. The lode was being worked at the bottom level; it was a narrow body, fairly well defined in places, poorly defined in others, carrying a few irregular lenses of quartz, with some ferruginous and manganiferous matter; the values were patchy, but generally poor. From a shaft near the north corner of the lease some work had been done on a parallel line about 60 feet further west, and of a similar character, but more poorly defined, and said to be worth from *nil* to 7dwts per ton. Associated with both formations were a number of cross quartz veins dipping to the north at from about 45 to 60 degrees, and apparently carrying some manganese.

Returns are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4499E, Williamstown	1,321·23	370·08	0·28

North End Extended G.M.L. 4485E.

This lease is situated south of and adjoining the Kanowna Road, slightly to the east of the Devon Consols and Sons of Gwalia. It was formerly part of G.M.Ls. 4046E, Hannan's Hope, 4369E, Colleen Bawn South, and 4157E (formerly 4047E), Hannan's Hope Extended, the northern portion at an earlier date forming parts of G.M.Ls. 3805E, Brown Hill Consols No. 2, prior to that G.M.L. 1268E, Brown Hill Consols North, while the southern portion was part of G.M.L. 1187E, Outridge.

The south-western portion of the lease is mainly in hornblendite, the north-eastern in fine-grained amphibolite. The northerly extension of the Westralia United lode runs, roughly, along the north-eastern boundary at the surface. It appears to be surrounded by a narrow strip of fine-grained greenstone. The jasper—previously mentioned in the description of those rocks as running towards this lode—runs through the southern portion of the lease, where it dips to the south-west at about 74 degrees, apparently marking the boundary between the Older and Younger Greenstones.

Some work has been done on the lode from a shaft, 77 feet deep, near the eastern corner of the lease, the lode having been driven on at the 48 and 77ft. levels, and stoped to some extent between them and the surface.

There are several other shafts on the lease, the workings of which were inaccessible; much of the surface has been dry-blown, particularly along a well-defined watercourse running across the southern portion of the lease. As the lode in the Westralia United has yielded very good shoots from time to time, its northerly extension will, doubtless, bear further prospecting.

Returns are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4485E, North End Extended ..	281·14	86·30	0·31
4046E, Hannan's Hope	15·00	1·24	0·08
4157E, Hannan's Hope Extended ..	..	2·62*	..
Totals	**296·14**	**90·16**	**0·30**

* Dollied and Specimens.

LUCKNOW G.M.L. 4464E. This lease adjoins the eastern boundary of G.M.L. 1228E, Red White and Blue, and was formerly G.M.L. 4006E, Hannans Oversight, and at an earlier date part of G.M.L. 3776E, Kalgoorlie Mount Morgan, and prior to that part of G.M.L. 1094E, Austral.

The lease is almost entirely in talc-chlorite rock, while the main line of jasper running south from G.M.L. 3771E runs along the eastern boundary; east of this is the main belt of fuchsite rock. Another smaller jasper runs through the latter in the southern portion of the lease. A small hill at the southern end of the ground is capped by dense laterite.

A long watercourse runs from G.M.L. 1228E through this lease and thence through the Westralia United leases; a good deal of dryblowing has been done in its vicinity. Near the northern end of the lease and close to the western boundary is a shaft 144 feet in depth, on the jasper, from which levels have been put in at depths of 51, 99, and 144 feet (*vide* Fig. 6). In these workings there are several smaller lenses of jasper close to and west of the main line; the latter dips to the east—its laminæ are a good deal contorted; the usual series of coarse flinty lenses is found on its eastern side. Sulphide rock is met with only at the end of the west crosscut at the 144ft. level; here the rock is hard, pale grey in colour, and highly carbonated; it appears to contain a little fuchsite.

On the top of the hill, in the laterite, is another shaft, said to be 200 feet deep, at which depth crosscuts run east and west; from the former is a winze to a total depth of 312 feet from the surface; the east crosscut is in jasper between the shaft and the winze. The dump of this shaft is mainly composed of highly graphitic schist. 200 feet north-east of this last shaft is another, said to be 100 feet in depth; it is in fairly typical talc-chlorite-carbonate rock. There are several shallow shafts on the ground in the vicinity of the laterite, but the northern portion of the ground does not appear to have been very well prospected.

Returns for the Lucknow are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4464E, Lucknow	31·00	3·91	0·13

North End Deeps, 4507E. This lease lies to the east of and adjoining the Lucknow. It was formerly G.M.L. 4312E Ellendale, and prior to that G.M.L. 4169E of the same name. With the Lucknow it also formed part of G.M.Ls. 3776E and 1094E.

The lease is almost entirely in hornblendite, the extreme eastern portion being in quartz-dolerite amphibolite.

There are only three shafts on the ground—all inaccessible.

Most of the ground at the northern end has been dryblown.

From the amphibolitic nature of the country rock, the occurrence of payable ore-bodies on this lease can hardly be expected.

There are no returns for this ground.

Bonnie Play G.M.L. 4088E. This lease adjoins the south-eastern boundaries of the Lucknow and the North End Deeps, and is mainly situated between the Parkestown and Bulong roads, close to their junction. The lease was formerly part of G.M.L. 1030E Hidden Treasure Extended.

A broad band of dolerite greenstone runs through the middle of the lease, west of that is talc-chlorite-carbonate rock, while a comparatively narrow band of hornblendite is found near the eastern corner; this latter rock apparently ends close to the north-east boundary; a narrow tongue of actinolite-zoisite amphibolite enters the lease from the south and runs north as far as the Bulong Road, while the western corner of the ground is in fuchsite-carbonate quartz rock.

There are apparently no lode-formations within this lease, but a number of cross veins of vitreous, somewhat oily-looking quartz, dipping to the north at about 80 degrees, have been worked at the 56ft. level from two shafts near the north-eastern boundary.

Near the western corner of the lease is a shaft 57 feet deep, near the eastern boundary of the fuchsite rock. At the 22ft. level from this shaft there are a number of quartz veins striking in various directions and with a fair amount of fuchsite round them. There are several other shafts on the ground, but nothing of value appears to have been struck in them, and apparently the only workable ore-bodies in the lease are the cross quartz veins in the band of dolerite greenstone.

A watercourse runs east through the middle of the lease, and a good deal of dry-blowing has been done in its vicinity.

Available statistics show a total of 83.61 tons treated for a return of 12.14 fine ounces—an average of 0.15 fine ounces per ton.

Dar Kan G.M.L. 4368E. This is a small triangular lease adjoining the south-eastern boundary of the North End Extended and the northern boundary of the North End Deeps, and is one of the Westralia United Goldfields, Ltd., leases. It was formerly part of G.M.L. 1187E Outridge.

The greater portion of the lease is in hornblendite, the northernmost portion being probably in quartz-dolerite amphibolite and fine-grained greenstone. The Westralia United lode runs across the lease close to the north corner.

There are three shafts on the ground, two in the vicinity of the lode.

Most of the surface has been dry-blown.

Devon Consols South Extended G.M.L. 4037E (Figs. 40 and 41 and Plate VI). This lease, which adjoins the south-eastern boundary of the Dar Kan and the north-eastern boundary of the North End Deeps, is the most important of the Westralia United Goldfields, Ltd., leases. It was formerly part of G.M.Ls. 1187E Outridge, 2679E Hannan's Hope, 1094E Austral, and 1136E Euclid.

The south-western two-thirds of the lease are in quartz-dolerite amphibolite—or the corresponding greenstone, in the vicinity of the lode—the remaining third in fine-grained greenstone. In the southern portion of the lease the lode appears to follow the junction of the Older and Younger Greenstones, turning into the former in the northern portion of the ground.

The main shaft is situated near the middle of the lease, west of the outcrop of the lode, which it cuts at a depth of 190 feet. Levels

have been driven at depths of 70, 160, 231, and 329 feet, the shaft itself being 335 feet in depth; north of the main shaft are several intermediate levels. As may be seen on the longitudinal section (Plate VI.), a great deal of stoping has been done, particularly in

Fig. 40.

Neg. F187.

Photo: F. R. Feldtmann.

Westralia United Main Shaft from North-West. Outcrop of lode marked by line of shafts.

the upper levels, where several very good shoots have been found; the general shape of these may be gauged from the section; values appear to have been generally erratic.

The lode channel is very wide, and there appear in the cross section through the main shaft to be two main lines, apparently

Fig. 41.

Photo: F. R. Feldtmann. Neg. F188.

Westralia United Open Cut from North.

joining to the north of the section, the western branch carrying the best values. At the 231ft. level the western branch seems to split

going down. At the lower levels values have been generally disappointing, only one small lens of good ore being found at the 329ft. level.

The general structure and composition of the lode has already been discussed when dealing with the ore-deposits in general.

As this lode channel appears to be a particularly strong one, there seems to be no reason why other shoots of good ore should not be found. It should be mentioned that since this mine was examined another shoot of rich ore has been picked up in the northern workings by Messrs. McPherson and Rae, and two parcels, totalling 204 tons, are said to have given a return of £1,310 (including gold in residues), or an average of well over £6 to the ton.

Euclid G.M.L. 4054e.

This is another of the Westralia United leases; it adjoins the south-eastern boundary of G.M.L. 4037e and covers parts of former G.M.Ls. 1094e and 1136e.

This lease is also partly in quartz-dolerite amphibolite, partly in fine-grained greenstone, the main lode running along the junction of the two rocks.

The lode is vertical in this lease; a small spur striking north and south, on the western side of the lode, joins the latter about 85 feet north of the "Euclid" shaft. This shaft has a depth of 144 feet and connects with the south drive at the 160ft. level from the main shaft in G.M.L. 4037e.

There were six other shafts on the lease at the time of my survey; the westernmost shaft, now inaccessible, being in typical quartz-dolerite amphibolite, it is unlikely that anything of value will be obtained therein.

Rising Sun G.M.L. 4039e.

This is the southernmost of the Westralia United leases. It is situated mainly between the Parkestown and Bulong Roads, and adjoins the Euclid and Bonnie Play leases. The western and larger portion of the ground was formerly covered by part of G.M.L. 1103e of the same name, the eastern portion forming part of G.M.L. 1038e, Hidden Treasure Consols.

Although there are a number of shafts on the lease, only the easternmost—the No. 4 shaft of the old Hidden Treasure Consols—has got below the oxidised zone, and that is in the spheroidal variety of the fine-grained amphibolite.

From the surrounding leases it is most likely that the western two-thirds of the lease are in dolerite-greenstone, and most of the remainder in fine-grained greenstone, a narrow strip along the

north-eastern boundary being in the corresponding amphibolite. The southerly continuation of the Westralia United lode runs into the lease; near its southern end it seems to leave the boundary of the Older and Younger rocks and run into the fine-grained greenstone. The schistose formation, on which a little stoping has been done from the drive off the east cross-cut at the 96ft. level from the "Sunrise" shaft, is probably the continuation of the main lode. There are a number of minor formations on the lease, west of the main lode and roughly parallel to it. In one of these, cut in a costeen north-west of the above shaft there is a band of green, flinty quartz, probably fuchsitic. The rich patch recently discovered by Messrs. Regan and Rowe, is probably on a spur running north-west from the main lode, and dipping to the south-west; from this patch a parcel of 28 tons was treated for a return of £1,220.*

Returns for the Westralia United Goldfields, Ltd., leases are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4037E, 4039E, 4054E, 4231E, 4368E, Westralia United Goldfields, Ltd.	1,719·77	504·80	0·29
4037E, 4039E, 4054E, 4231E, Rising Sun Leases	294·00	98·78	0·34
4039E, Rising Sun Lease	186·00	30·38	0·16
4037E, 4039E, 4054E, North End Mines, Ltd.	1,812·00	883·27	0·49
4037E, 4039E, 4054E, North End Gold Mines, Ltd.	5,876·00	2,425·03	0·41
4037E, 4039E, 4054E, 4231E, 4368E, Devon Consols S. Ex. Leases	8,269·14	2,712·76	0·33
4037E, 4039E, 4054E, Devon Consols S. Ex. Leases	2,251·00	1,400·94	0·62
	20,407·91	**8,055·96**	**0·39**

Fair Play G.M.L. 4052E.

This lease lies to the south-east of the Bonnie Play and south of the Bulong Road, and together with G.M.L. 4063E, Fair Play Extended, is held by Messrs. Tregowarth Bros. and Quirk. It was formerly part of the Hidden Treasure Extended G.M.L. 1030E.

The western portion of the lease is partly in hornblendite, partly in talc-chlorite-carbonate rock, with actinolite-zoisite amphibolite at the western corner; the eastern portion is mainly in dolerite greenstone, with the talc rock again at the southern corner. The dolerite greenstone is found outcropping on a small rise near the centre of the lease.

* *Vide* the *West Australian* of 10th March, 1915.

The main lode runs through the eastern portion of the lease about 115 feet west of the east corner; a number of small spurs apparently run from it in a north-westerly direction. There were only four shafts on the lease and some costeens near the southern end, most of the work on the lode having been done on the adjoining Fair Play Extended.

Two watercourses run through the north-western portion of the ground, joining before reaching the north-east boundary; a good deal of dryblowing has been done in their vicinity.

Fair Play Extended G.M.L. 4063E.

This lease is an irregularly-shaped block adjoining the Sunrise and Fair Play leases. The northern portion of the lease was formerly part of G.M.L. 1038E, Hidden Treasure Consols, while the southern portion was held as G.M.L. 1137E, Golden Gully North.

The extreme north-eastern portion of the lease is in fine-grained greenstone; this being seen in a long cross-cut at the 100ft. level, running from below the Bulong Road to the north-eastern boundary of the lease. The rock in this cross-cut was a good deal sheared—the junction between the Older and Younger Greenstones occurs in the western portion of the cross-cut, but the rocks in the vicinity were highly weathered, and it was almost impossible to determine its exact position. The north-western portion of the ground is in dolerite-greenstone, with the talc-rock to the south of this, while a narrow band of quartz-dolerite amphibolite runs along the eastern boundary; the latter is found east of the main shaft and close to a watercourse, which runs along the eastern boundary.

The main shaft (*vide* Fig. 16) is situated close to the north-eastern boundary of G.M.L. 4052E, and the outcrop of the lode runs about 12 feet east of the shaft. The general strike of the lode channel is nearly north and south, and the dip is variable, but in general steeply to the west. About 60 feet north of the shaft, at the surface, the lode splits, the western branch striking slightly west of north, the eastern about N.N.E. At, roughly, 100 feet N.E. of the shaft at the surface, and striking N.W.-S.E., is another sheared zone, coloured green by fuchsite; this sheared zone dips to the south-west at about 70°. It appears to have formed the hanging wall to the ore shoots, of which three have been worked between the surface and the 197ft. level. These all occurred along the eastern branch to the north of the green sheared zone, and south of another and smaller line of shearing roughly parallel to the first. This second shear plane apparently acting as the footwall of the shoot between the surface and the 107ft. level. Some specimen telluride ore was obtained in the stope on the third shoot below the 162ft. level.

Levels have been put in from the main shaft at depths of 107, 145, and 197 feet, and there are several intermediate levels. At the time of my visit the owners were driving on the lode south of the main shaft, at the bottom level. A little work has been done on the lode from a shaft in the southern portion of the lease. Levels have been put in at depths of 54 and 93 feet from this shaft. There is another N.W.-S.E. striking, fuchsitic formation at these workings, associated with a small albite-porphyrite dyke. The main lode seems to be represented here by a thin fuchsitic seam. Values up to about 15dwts. were obtained near its junction with the N.W.-S.E. striking formation.

From a close examination of the mine it would appear that patches of ore are found where the N.W.-S.E. formations join the main N.-S. line of lode. The richest shoots occurred in a highly shattered area, where, in addition to the cross sheared zones, the lode itself had split.

In the search for other shoots it might be as well to follow the line of junction between the two branches.

Returns for the Fair Play leases are given below:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4052E, 4063E, 4319E*, Fair Play Leases	2,786·50	3,906·34†	1·40

* Now voided. † Includes 4·77 fine ozs. dollied and specimens.

Isabel G.M.L. 983E (voided).

This lease was situated to the south-east of, and adjoining the Fair Play Extended. The ground is in fine-grained greenstone, with the exception of the narrow band of quartz dolerite derivatives on the western boundary. The narrow N.-S. formation mentioned in the description of the fine-grained greenstones runs roughly parallel to and between one and two chains east of the western boundary and the two main lines of lode, approximately parallel to each other, appear to turn slightly and run into it at, roughly, 100 and 330 feet, respectively, south of the northern boundary of the lease. There are other smaller probable lines of lode on the ground.

The main shaft is situated east of the main lodes near the centre of the lease; some long cross-cuts were put in east and west at the 177ft. level, nearly across the lease; these and all other workings, with the exception of the drive on the west lode at the 64ft. level, were inaccessible. Both lodes are approximately vertical. A

fair amount of work has been done on both, but particularly on the western lode, which has been driven on for over 600 feet at the 177ft. level. Like most of the lodes in the fine-grained greenstones these lodes appear to have been patchy.

Returns for the lease are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
983E, Isabel	5,302·26	1,415·85*	0·27

* Includes 108·44 fine ozs. Dollied and specimens.

CRESWICK G.M.L. 4515E (voided).

This lease was situated south of the Isabel and was formerly G.M.L. 3991E, Hird's lease, and prior to that G.M.L. 547E, Mt. Ferrum. The western portion of the ground is in quartz-dolerite greenstone, the eastern in fine-grained greenstone.

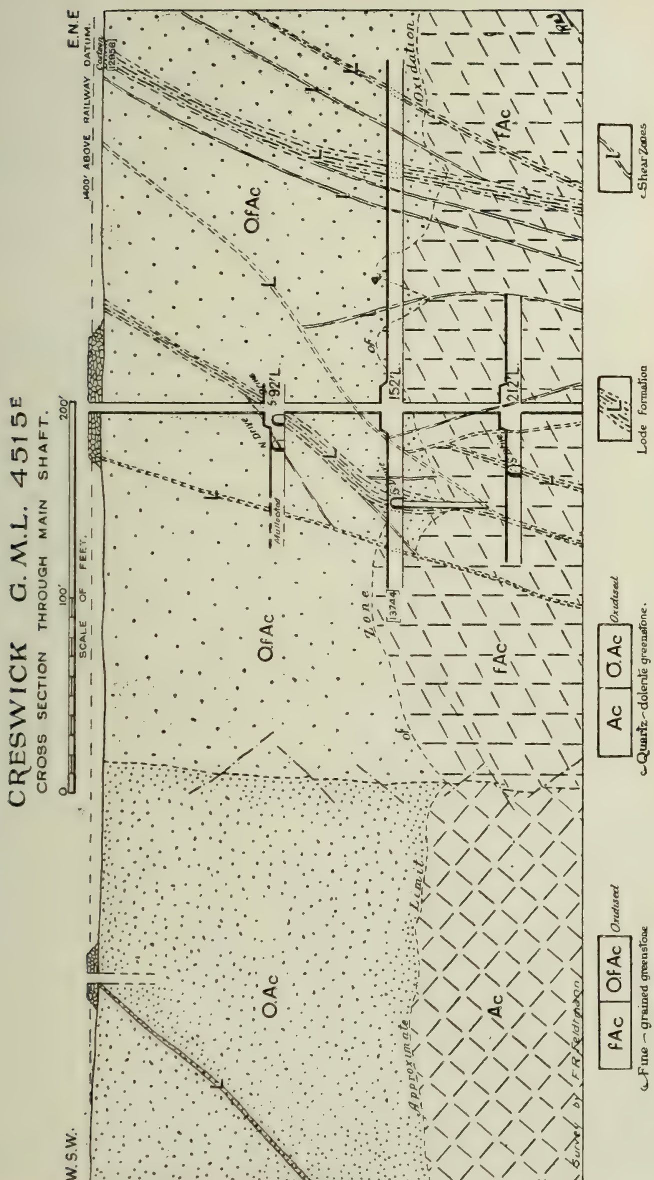
The previously mentioned N.-S. formation does not occur at the junction of the two rocks in this lease, but in the quartz-dolerite greenstone between 50 and 100 feet away from the junction at the surface, and dipping to the west at a little over 50 degrees, away from the junction. Close to the northern boundary of the lease another formation, striking N.W.-S.E., ran into the N.-S. lode from its eastern side, and a small shoot of ore, carrying fair values was struck at the junction; this was being worked by Messrs. Nelson Bros. at the time of my survey.

A fair amount of driving had been done on the N.-S. lode, at the 56 and 100ft. levels from a shaft 290ft. south-east of the north-west corner. A number of cross quartz veins were cut in these drives, on which some stoping had been done.

The old main shaft is situated near the centre of the lease in fine-grained greenstone; it is 366 feet in depth, but only the 92, 152, and 212ft. levels were accessible.

As may be seen on the cross section (Fig. 42), the fine-grained greenstone in the vicinity has been much sheared and shattered, but no really payable ore bodies appear to have been encountered. Small quantities of tellurides are said to have been obtained at the 212 and 352ft. levels.

Fig. 42.


CRESWICK G.M.L. 4515E
CROSS SECTION THROUGH MAIN SHAFT.
SCALE OF FEET.
0
100'
200'
W.S.W.
E.N.E
1400' ABOVE RAILWAY DATUM.
O.Ac
Of Ac
fAc
Ac
92' L.
152' L.
212' L.
N Drive
Mullocked
Zone of Oxidation
Approximate Limit of
fAc
Of Ac
Oxidised
Fine - grained greenstone
Ac
O.Ac
Oxidised
Quartz - dolerite greenstone.
Lode formation
Shear Zones
Surveyed by F.R. Feldtmann

Returns are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
4515E, Creswick	1,404·86	261·40	0·19
3991E, Hird's Lease	1,152·47	1,217·63*	1·14
547E, Mt. Ferrum	20·00	21·91	1·10
	2,577·33	**1,500·94***	**0·58**

* Includes 42·85 fine ozs. dollied and specimens.

A.W.A. United G.M.L. 4441E (voided).

This lease adjoined the southern boundary of the Creswick lease, and was formerly G.M.L. 4051E of the same name. Prior to that the ground was covered by G.M.L. 1490E, Mt. Ferrum.

The western and greater portion of the lease is in quartz-dolerite greenstone, the eastern in fine-grained greenstone. Close to the eastern boundary of the lease is a prominent laterite-capped hill—Mt. Ferrum, of which mention has already been made when dealing with the secondary impregnations in the zone of oxidation. The main N.-S. formation runs from the Creswick through the middle of the lease; it is here mainly in the quartz-dolerite greenstone, but at the southern end of the lease it leaves that rock and runs into the fine-grained greenstone. A little work was done on this formation from the 185ft. level from the main shaft, which is 400 feet deep, and is situated 200 feet north-east from the middle of the south-west boundary. A little work has been done on the same formation from the 93ft. level from a shaft close to the north-eastern boundary, but values seem to have been generally poor. The westernmost workings on the lease, on the continuation of the Hidden Secret South lode, have already been mentioned when dealing with that mine. This lease has been well prospected, long crosscuts having been put in west of the main shaft at the 185 and 400ft. levels and east of the main shaft at the 400ft. level, while east and west crosscuts were put in at the 92ft. level from No. 4 shaft on the northern slope of Mt. Ferrum. In addition three diamond-drill bores were put in from the 400ft. level, two from the western end of the west crosscut, the one dipping south-west, the other north-east, to vertical depths of 673 and 994 feet respectively below the surface level of the main shaft; the third from the eastern end of the east crosscut to a vertical depth of 902 feet below the same datum.

These leases formed part of the A.W.A. United leases, returns for which are given below:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
1101E, 4051E, 4070E, 4230E, 4275E, 4281E, 4302E, A.W.A. United Leases	59,640·50	14,017·42	0·24
3890E, 1101E, 1111E, Brown Hill Junction G.M. Co., N.L.	1,122·00	327·15	0·29
4200E, Mt. Ferrum Consols ..	32·00	4·35	0·14
4070E, Badra	30·00	10·15	0·34
	60,824·50	**14,359·07**	**0·24**

Brownhill Junction G.M.L. 1101E and Mt. Ferrum Consols G.M.Ls. 4230E and 4275E (all voided). (Fig. 43 and Plates IV., V., and X.).

For convenience these three leases will be considered together; all belonged to the A.W.A. United group of leases. G.M.L. 1101E adjoined the south-eastern boundary of G.M.L. 4441E and the other two were situated south-east of the former. G.M.L. 4230E was formerly held as G.M.L. 4200E of the same name, and prior to that formed part of G.M.L. 3826E, Brown Hill Junction South, and at an earlier date G.M.L. 960E, Evening Star, while G.M.L. 4275E also formed parts of the last two leases and also G.M.L. 853E, Gem.

These leases are entirely in fine-grained greenstone. A fairly well defined and broad lode channel, in which there are three parallel lines of lode, runs through these leases; the middle line proved the best of the three, although a fair amount of work was also done on the western line, which apparently joins the middle line between the 199ft. and 300ft. levels in the section through the main shaft (*vide* Plate IV.). The rock in the vicinity of these two lines is highly brecciated. The main shaft, which is 400 feet deep, is situated on G.M.L. 1101E, and from it levels have been put in at depths of 98, 150, 199, and 300 feet, and drives north and south have been put in beyond the boundaries of the three leases at the 98ft. level and for nearly the same distance at the 199ft. level; these drives are on the middle lode, but a number of crosscuts were put in to the west lode, which was stoped out in places, while a great deal of stoping has been done on the middle lode between the surface and the 199ft. level. Some of these stopes are shown on the longitudinal section (Plate V.), but, unfortunately, nearly all are inaccessible, and their full extent could not be surveyed. In addition, the lodes have been worked in a series of large open-cuts; there has

evidently been some impregnation of the surrounding country, from the width of rock taken out from these open-cuts.

A good deal has already been said about these lodes in that portion of the report dealing with the lodes in the fine-grained greenstones.

Fig. 43.

Photo: F. R. Feldtmann. Neg. F201.

Brown Hill Junction Main Shaft and Open Cuts from the North-West.

In addition to the mine workings, the country has been prospected by diamond drilling, two bores having been put in to the

east and west from the 300ft. level—dipping at angles of 19 and 33 degrees—to total depths of 478 and 588 feet, respectively, below the surface level at the main shaft. Nothing of value, however, was struck in these bores.

The two northern leases have been well prospected, but little work, however, has been done on the most southerly of the three.

Badra G.M.L. 4070E (voided). This was another of the A.W.A. United leases, and was situated north-east of and adjoining G.M.L. 1101E. It was formerly part of G.M.L. 987E Etra Weenie. The ground is entirely in fine-grained greenstone.

There are three shafts on the ground, all inaccessible; the northernmost is said to be about 125 feet deep, and east and west crosscuts have been put in at the 90ft. level to the boundaries of the lease; the middle shaft is 210 feet deep, and crosscuts were driven to the boundaries at the 200ft. level; from the north-east crosscut at this level a diamond drill bore was put in at a dip of 30 degrees to a total depth of 379 feet below the surface level at the shaft.

Although several lines of lode run through the lease, no payable values have been encountered, and the ground has been too well prospected to permit of any hope for the discovery of payable ore-bodies in the future.

Returns for this lease are included in those for the A.W.A. United leases.

Mt. Lily G.M.L. 4404E (voided). This lease adjoined the Badra and Mt. Ferrum Consols leases, and was formerly held as G.M.L. 988E Clare Innis and part of G.M.L. 922E Herlichite, both belonging to the Brownhill Proprietary G.M. Co., Ltd.

A line of lode runs from the Badra into the northern portion of this ground, which is entirely in fine-grained greenstone; some costeening has been done on this formation and a shaft sunk on its eastern side—apparently without success. About half-way down the lease there is a long line of alluvial workings running right across the lease. As can be seen by the returns, a fair amount of gold was obtained from the Clare Innis, but from what workings, there is no record to show; most, however, probably came from this alluvial line. Another line of lode runs through the south-eastern portion of the ground, on which a shaft 300 feet deep and a number of shallow shafts have been sunk; old mine plans show drives on this lode at depths of 40 and 75 feet and a crosscut at 125 feet, but only a portion of the former level was accessible at the time of

my survey. Judging by the returns, fair values were obtained in these upper levels, but there are no records as to the value of the lode at depth.

Returns for the ground are as follows:—

Name and Number of Lease.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
988E, Clare Innis	379·00	505·38	1·33
922E, Herlichite	280·50	173·23	0·62
	659·50	**680·61**	**1·03**

F. R. FELDTMANN,
FIELD GEOLOGIST.

27th March, 1916.

CONTRIBUTIONS

TO THE STUDY OF

THE GEOLOGY AND ORE DEPOSITS OF KALGOORLIE, EAST COOLGARDIE GOLDFIELD.

———o———

Part I.—Bulletin 42, **1912:—**

1. Geology of Kalgoorlie and Boulder. C. G. Gibson.
2. Composition and Internal Structure of the Kalgoorlie and Boulder Ores. E. S. Simpson.
3. Detailed Mineralogy of Kalgoorlie and Boulder. E. S. Simpson.
4. Surface and Underground Waters. E. S. Simpson.
5. Natural Gas in the Boulder Mines. E. S. Simpson.
6. The Constitution of the Native Tellurides. E. S. Simpson.
7. The Analyses of Telluride Minerals. E. S. Simpson.

Part II.—Bulletin 51, **1913:—**

8. The Geological Features of part of the Northernmost portion of the Kalgoorlie Auriferous Area. F. R. Feldtmann.
9. The Petrology of part of the Northernmost portion of the Kalgoorlie Field. R. A. Farquharson.

INDEX.

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

INDEX—*continued.*

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BY

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